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Brain potentials in patients with music perception deficits: evidence for an early locus

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Abstract

Twelve patients with an acute cerebrovascular accident were assigned to a group with music perception deficits (amusia, $n = 6$) or a group without such deficits ($n = 6$) on the basis of a new test-battery for music-perception skills. Event-related brain potentials (ERPs) were recorded in an auditory classification task designed to elicit several components; the N1 as a correlate of initial auditory cortical processing, the P3a as an index of automatic attentional orienting, and the P3b as a measure for controlled stimulus evaluation. Patients with amusia showed a significant amplitude decrement for the P3a relative to controls and patients without amusia suggesting an impairment of early stimulus evaluation. P3b was reduced in both patient groups relative to control. These data show that amusia is quite common in unselected stroke patients and suggest deficits of generic rather than music-specific cognitive processes as the underlying cause.

Keywords: Event-related potentials; Stroke; Music perception; Amusia; P3; P3a

While the neuropsychological literature abounds with descriptions of patients with aphasia, apraxia and agnosia, reports on amusia, i.e. an impairment of music perception due to cerebral lesions, have been relatively scarce [2,9–11]. This is partly due to the fact that unlike speech and language music perception and processing is a highly individual skill depending mainly on early exposure and training [5]. A few studies suggest, however, that music perception difficulties may in fact be more common after brain lesions than previously thought [8,10,13]. Little is known about the neuronal networks underlying music perception, the cognitive organization of these networks (i.e. are there specialized modules for the perception of pitch/rhythm/harmonics and so forth), and the contribution of non-specific generic cognitive mechanisms such as attention and memory to music processing.

In the present study, as a first step to answering these questions, unselected patients with an acute unilateral cerebro-vascular lesion were tested by means of a specific test battery 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 [14]. Based on whether or not the patients' receptive musical abilities were impaired, we classified them into two broad groups. These two patient groups and an age-matched control group were tested in a simple auditory classification task with simultaneous recording of the event-related brain potentials (ERPs). ERPs are small voltage fluctuations that can be recorded non-invasively from the intact scalp. Their peaks and troughs (components) can be related reliably to cognitive operations [12]. There were four different stimulus categories: (1) standard tones (1000 Hz, 60 ms duration, probability 0.7), target tones (2000 Hz, 60 ms duration,

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Table 1

Results for the subtests on the music tests (errors in %SE)

Test	Amusia	No amusia
Pitch-differences	17.9 (4.1)	4.1 (4.1)
Melody changes	36.4 (2.7)	22.5 (5.0)
Rhythm changes	42.9 (4.0)	21.5 (5.4)
Metric changes	44.1 (2.3)	29.5 (3.3)

probability 0.1), novel sounds (25 different environmental sounds, e.g. a dog's bark, group probability 0.1), and deviant tones (1500 Hz, duration 60 ms, probability 0.1, these will not be reported as they led to similar ERPs as the target tones). Altogether 2000 stimuli were presented in random order at approximately 70 dB SPL with the subjects task being to press a button whenever they recognized a target stimulus. This task was designed to elicit three prominent ERP components which have been fairly well-studied in the past: the N1 component as an answer of the primary auditory cortex [4] should be obtained for all stimuli in an obligatory fashion. Its amplitude has been shown to be modulated by attentional factors [4]. The P3a component a fronto-centrally distributed positivity with a peak around 300–350 ms is usually obtained for novel stimuli and has been interpreted as a neural reflection of orienting attention towards new input [3,6,7]. Finally, the P3b component is found for task relevant target stimuli and has been related to the effortful processing of stimuli with its amplitude related to the amount of cognitive resources available [1,15]. Finally, all patients and controls were tested in several subtests of the computerized test-battery for attention disorders of Zimmermann and Fimm [16].

Out of a group of 17 patients with acute cerebro-vascular lesion (exclusion criteria: previous stroke, disseminated neurological disease, sedating drugs, hearing impairment, unspecific changes of attention and perception) the data of 12 could be used. One patient had to be rejected for her unability to do the music test, four others had too many artifacts during the EEG session to yield meaningful ERPs. Of the remaining group six patients (PAT-A, four left, two right hemisphere lesions, two women, 65 years, SD 4.6) showed dissociated deficits in music perception revealed by the music test-battery, while six (PAT-NA, four left, two right hemisphere lesions, two women, 47 years, SD 19) did not (see Table 1 for results). A control group of neurologically healthy subjects matched for age,

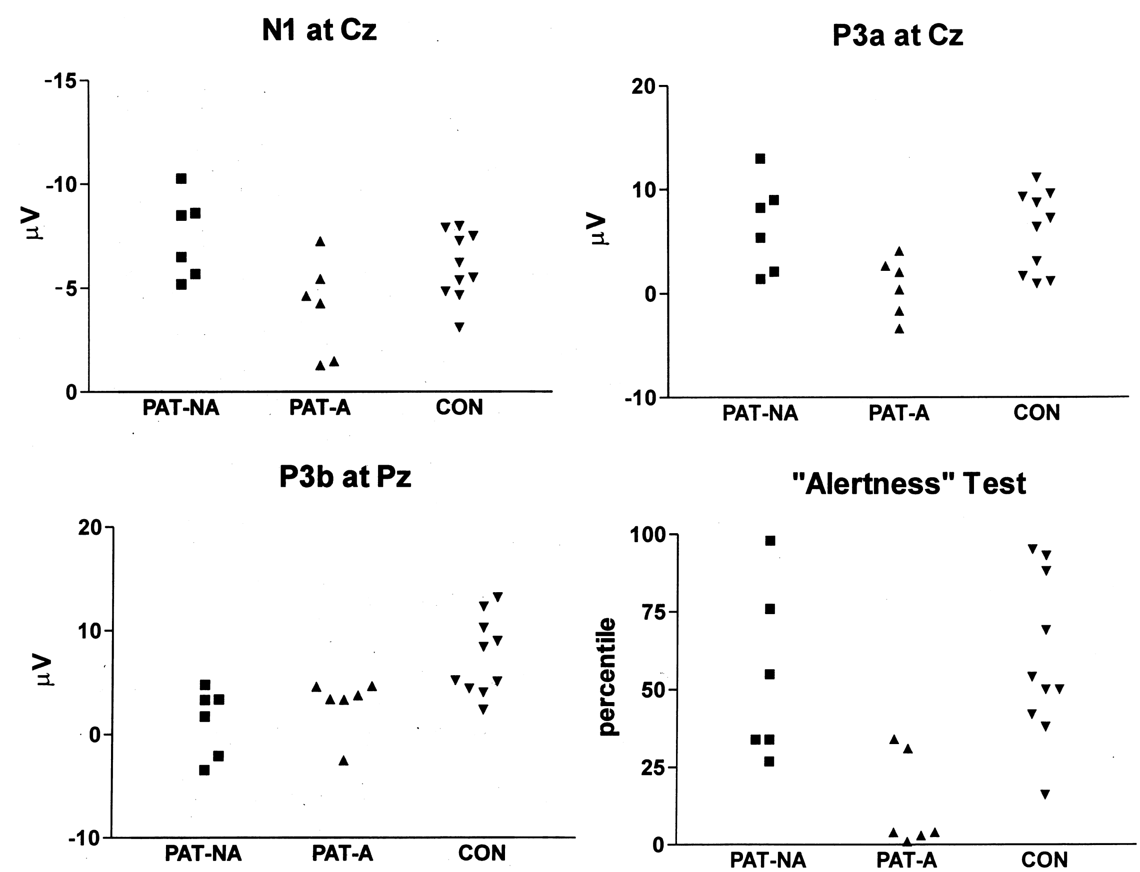

Fig. 2. Scattergrams showing the individual component amplitudes at the site of the maximum effect and the results of the Alertness test (simple auditory reaction time). The variance within groups is quite similar. For the P3a and the Alertness test the patients with amusia showed a marked effect, while for the P3b component both patient groups showed reduced amplitudes relative to the control group. PAT-NA, patients without amusia; PAT-A, patients with amusia; CON, control subjects.

sex, handedness, educational background and musical training (CON, four women, 57 years, SD 11) was investigated as well. All tests were performed 5–10 days postlesion.

ERPs were recorded from 19 tin electrodes (10/20 system) mounted in an Electro-Cap and referred to 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 different components were quantified by mean amplitude measures for the stimuli and electrodes for which they yielded maximal amplitude (N1: standard stimuli, Cz, 80–120 ms; P3a: novel stimuli, Cz, 300–400 ms; P3b: target stimuli, Pz, 300–600 ms). These data were compared by analysis of variance followed up by Tukey's post-hoc test for differences between the three groups.

Fig. 1 illustrates the grand average ERPs for the three groups and the different stimuli for the midline electrodes. The standard stimuli and all other stimulus classes are characterized by an N1 component peaking at about 120 ms. This seemed to be somewhat smaller in the PAT-A-group ($F_{2,19} = 4.78$, $P < 0.03$, Tukey PAT-A/PAT-NA $P < 0.05$, all other $P > 0.05$). The scattergrams (Fig. 2a) show that the variance within the three groups is similar for these components and that in fact the amusia group has the smallest amplitude. A more striking difference between the groups was found for the P3a component, which was virtually absent in the PAT-A group, while it was well preserved in the patients without music perception deficits. This was reflected in a significant group difference for this component ($F_{2,19} = 4.54$, $P < 0.03$, Tukey PAT-A/CON $P < 0.05$, PAT-A/PAT-NA $P < 0.05$, PAT-NA/CON n.s). Finally, for the P3b component, a parietally maximal component to the target stimuli both patient groups showed a smaller amplitude than the controls ($F_{2,19} = 7.17$, $P < 0.005$, Tukey PAT-A/CON $P < 0.01$, PAT-A/PAT-NA n.s., PAT-NA/CON $P < 0.05$). The results for the computerized attention test-battery [16] indicated attention deficits in the patient group with amusia. In the 'Alertness' test, for example, a simple auditory reaction time test, patients with amusia performed worse than the other two groups ($F_{2,19} = 7.4$ $P < 0.005$, Tukey PAT-A/CON $P < 0.01$, PAT-A/PAT-NA $P < 0.05$, PAT-NA/CON n.s., see also Fig. 2). The number of patients was too small to further differentiate according to damaged hemisphere or specific music perception deficits.

Therefore, the current findings should be interpreted with caution. Even so, it appears that the brain potentials correspond to the differential involvement of music perception abilities in the two patient groups. Only the patients with amusia show a nearly complete loss of the P3a component. This component is obtained to novel stimuli, i.e. such stimuli that require the orienting of attention and it has been viewed as an automatic process [3,6,7]. These findings sug-

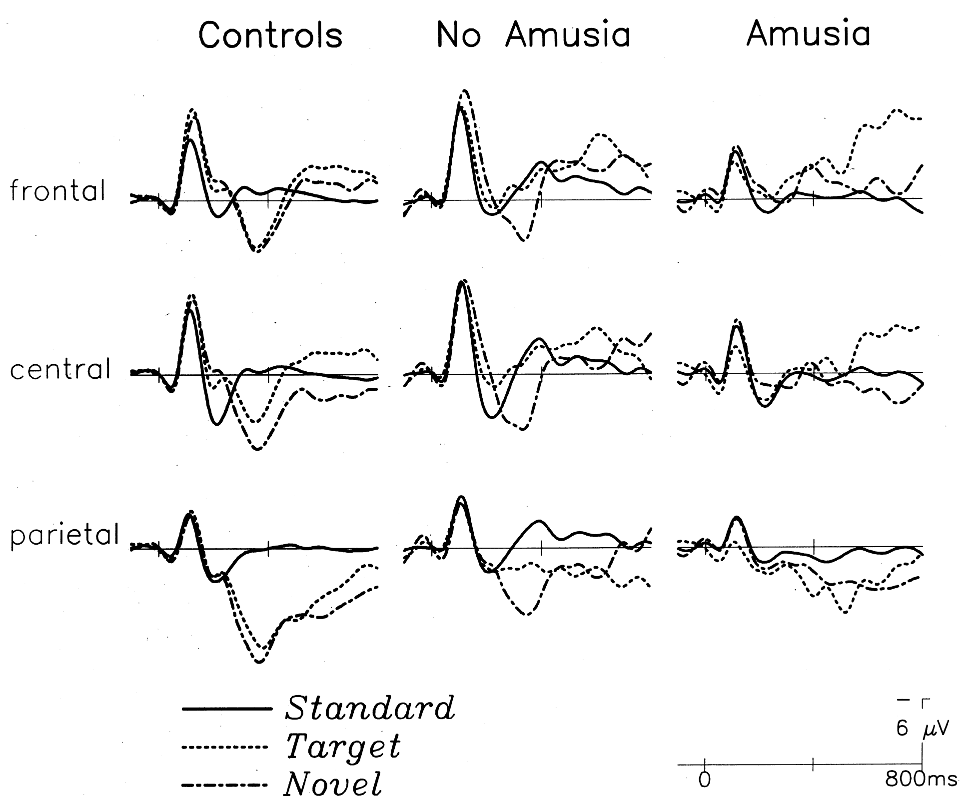

Fig. 1. Group averages for the patient and control groups. Patients with amusia show a smaller N1 and most crucially a nearly complete loss of the P3a component. The parietal P3b component for the target stimuli on the other hand is reduced in amplitude for both patient groups. ERPs to deviant non-target stimuli are omitted as they show a P3b component of smaller amplitude than the target stimuli.

gest that the music perception deficits found in these patients are likely due to difficulties with basic stimulus classification. Moreover, the reduced N1 component in these patients might indicate some attentional difficulties as well. On the other hand, the P3b component that is associated with effortful, controlled stimulus evaluation processes appears to be affected in both patient groups regardless of music perception deficits. It is therefore unlikely that later controlled processing stages are crucial in the music perception deficits revealed by the music test. In a necessary and crucial next step of our project we will try to establish a relationship between lesion-site, lesion-size and the specific behavioral deficits. Moreover, it seems important to assess the longevity of the music perception deficits and their relation to domain general cognitive deficits by follow-up investigations.

However, even at this early stage of our project it seems safe to draw several conclusions: (1) music perception deficits appear to be quite common in unselected stroke patients, (2) while more specific higher order music perception deficits have been documented [8,9] it appears that basic auditory stimulus-classification is impaired in many of these unselected patients, (3) electrophysiological measures can be used to pinpoint the cognitive locus of the music perception deficits.

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