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Effect of Musical Modelling on Late Auditory Evoked Potentials*

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Summary. Late auditory evoked potentials were recorded in four subjects during musical tasks. A PDP 12 computer synchronized stimuli, which were produced by an integrated circuit, and recording with the help of a quartz time basis. The content of each experiment was different modelling of an ambiguous identical acoustic stimulus. In experiment 1, subjects had to model a 6-note melody according to the classic metric foot. In experiment 2, segmentation of an 8-note melody into 5- and 3- versus 3- and 5-tone motifs had to be performed. In experiment 1 an intra-individually reliable, but inter-individually variable neurophysiological correlate was detected during the heavy tone: (1) positivity, (2) negativity, (3) alpha blocking and (4) DC shift. Experiment 2 yielded an intra- and inter-individually reliable positive DC shift of about 4 μV between the two motifs. Myogenic, ocular, dermal, respiratory or electrocardiographic artefacts were excluded in each case. The results indicate that conclusions from evoked potentials to musical perception might be possible and that possible modelling mechanisms with subsequent undesirable influence on recordings have to be considered in any kind of evoked potential experimental design.

Key words: Music – Perception – Motif – Metre – Auditory evoked potentials

Introduction

Modelling or forming of acoustic stimulus material is a well-known phenomenon. Terms of everyday life like "tick-tock" instead of "tick-tick" or "click-clack" instead of "click-click" give proof of that. In 1874, Wundt described metre forming of acoustically identical tones as "subjective rhythmization". Another type of modelling is integration of several subunits to a higher unit as evidenced by gestalt perceptions. Although these phenomenons are ubiquitous – also in music (Thomson 1983) – there have been no trials to correlate them with evoked potentials, a physiological parameter known to be very close to consciousness. Moreover, in psychophysiological evoked potential experiments the stimulus is generally regarded as invariable, the variable to be studied systematically being the subsequent cognitive reaction.

Metre and motif are musical constructions which mostly are acoustically determined resulting in psychoacoustic parallelism. Variations in loudness or timing may be acoustic cues for identifying or forming the metre (Steedman 1977; Longuet-Higgins and Lee 1982). However, by choosing suitable melodies, the acoustic parameters can be ambiguous and metre or motif may be perceived or consciously modelled in different ways. By means of those two kinds of musical modelling, i.e. forming of metre and motif, this study was to investigate the effect of stimulus modelling on late auditory evoked potentials (AEP).

* Dedicated to Prof. Dr. J. Peiffer

Methods

Subjects. The sample was comprised of four highly motivated subjects (ss), 2 females (21 and 23 years) and 2 males (24 and 57 years), with no known neurological, psychiatric or hearing deficits. None had previous experiences in neurophysiological experiments. All ss were musical amateurs and familiar with at least one instrument.

Physical Environment. The ss sat comfortably in a reclining chair inside a dimly lighted, sound-attenuated and electrically shielded chamber, receiving the stimuli through headphones to the left ear.

Recording System. A PDP 12 computer synchronized stimulus presentation and recording by means of a quartz time basis. The AEP were recorded from Fz, Pz and Oz of the international 10–20 system, referenced to the right cheek-bone, using silver/silver chloride electrodes attached with rubber bands to the head. The ground electrode was placed on the right forearm. Pre-amplify 5,000, input impedance 10^9 ohm, system bandwidth 0.3–5,000 Hz, sampling rate 1016/stimulus melody. During the inter-stimulus interval (2,000 ms) an automatic drift analysis was computed; 50 raw EEGs per figure were averaged on line.

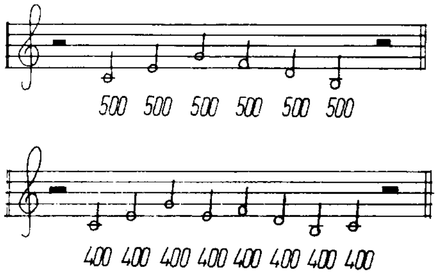

Fig. 1. Stimuli which had to be modelled metrically (experiment 1, upper line) and motifically (experiment 2, lower line). a1 = 440 Hz, intensity 50 dB SL, tone duration 500 ms and 400 ms, inter-stimulus interval 2,000 ms

Stimuli. Rectangle tones were generated by an integrated circuit (programmable sound generator, Special Electronic KG), with a1 = 440 Hz, intensity 50 dB SL, tone duration 500 ms (experiment 1) and 400 ms (experiment 2). Stimulus melodies of both experiments are depicted in Fig. 1.

Procedure. Some days before the experiments ss received a tape with the stimuli as well as instructions. In each experiment ss had to form identical ambiguous stimulus material in two different ways.

Experiment 1: ss were informed about the role of the waltz as a prime example of metre forming. It was explained that there were automatically formed identical notes in heavy and light elements, for example during the beating of a metronome (tick-tock, not tick-tick). The ss were told to try different metres and to nominate at least two of them, which were easiest to perform.

Metres used:

Metre	symbolic
dactyl	– u u – u u
trochee	– u – u – u
anapest	u u – u u –
iamb	u – u – u –
amphibrach	u – u u – u

Experiment 2: ss had to segment the 8 notes into 2 motifs in two different ways (5 and 3 notes and 3 and 5 notes). For clarification the musical slur was indicated. When ss had become familiar with the different kinds of forming without effort, each forming was recorded at least five times.

Control of Artefacts. Vertical-horizontal electro-oculography and the ECG were recorded and averaged to ensure the absence of electro-ocular and cardiogenic artefacts. Control of possible tongue or vocalization movements was achieved by the instruction to open the mouth slightly during the experiments. Skin potentials were prevented by scratching the skin below the electrodes according to the method described by Picton and Hillyard (1972). Moreover, EEG samples exceeding a fixed amplitude width of 130 µV were excluded from averaging (on average about 30%). In order to estimate artefacts by respiration or movement, ss were observed and later asked to observe themselves. No modelling-related movements could be detected. Additionally, experiments with modelling simultaneous respiration or movements were carried out, in which either inspiration and expiration or foot-knocking paralleled the modelled motifs and metres.

Measuring and Statistical Evaluation. Latencies and amplitudes were measured semi-automatically using computer software. In experiment 1 amplitude differences between N1 and P2, in experiment 2 P2 amplitudes relative to the averaged baselines were measured. Amplitudes of the first tone of a melody were excluded. For heavy and light tones and for tones of the first and the second motifs mean values and SDs were calculated.

Results

Experiment 1

During the heavy tones, a distinct, intra-individually reliable, but inter-individually variable evoked potential component was detected for each subject. Representative examples of the four subjects are plotted in Fig. 2–5. In the first subject there was a clearly visible positivity during the whole heavy tone (Fig. 2, maximum 6 µV amplitude, peaking at the middle of the tone, Fz > Pz, absent at Oz), with high

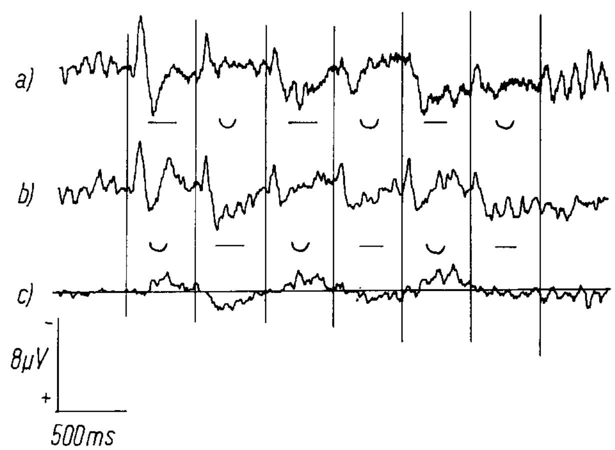

Fig. 2. Trochee (a) and iamb (b) modelling of the identical acoustic stimulus. In c the subtraction b–a, revealed positivity during the heavy tones. Note the "deep" P2 peak of heavy tones. Fz, subject 1

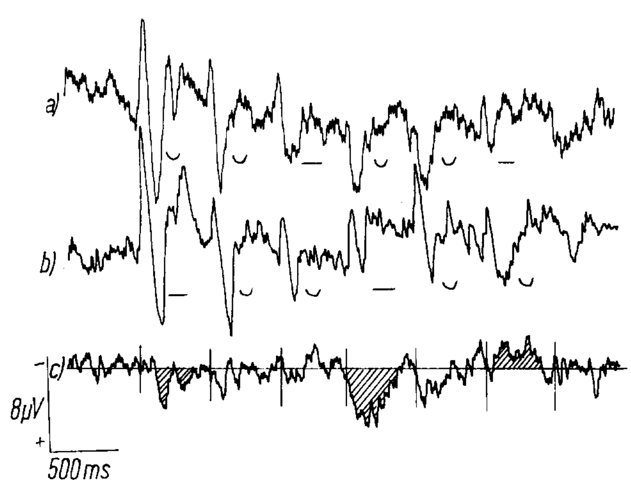

Fig. 3. Anapest (a) and dactyl (b) modelling, c was the subtraction a–b. Note the "high" P2 peak of heavy tones in a and b as a consequence of the negativity during heavy tones (hatched in c). Fz, subject 2

amplitudes of N1P2, resulting in clear detection of heavy tones by deep P2 peaks (average N1P2 amplitudes: light tones: 5.0 µV, SD 2.86 µV, 25 tones; heavy tones: 10.5 µV, SD 2.67 µV, 25 tones). In the second subject almost the reverse occurred: a superimposed negative potential during the heavy tone (Fig. 3, 2 to 5 µV amplitude, Fz = Pz, absent at Oz) was well-detected by "high" P2 peaks (average N1P2 amplitudes: light tones: 5.7 µV, SD 1.84, 30 tones; heavy tones: 2.8 µV, SD 1.85 µV, 20 tones). In the third subject a constantly increasing negativity during the note before the heavy tone was present at frontal and parietal locations. Additionally the superimposed 10 Hz waves, especially at Oz, diminished during the heavy tone (Fig. 4). Finally, the fourth subject presented with a positive DC shift at Fz and Pz between tone 3 and tone 4 only with dactyl forming (Fig. 5) as opposed to other metres, where no correlate was visible. No significant latency differences between potential components of light and heavy tones could be computed.

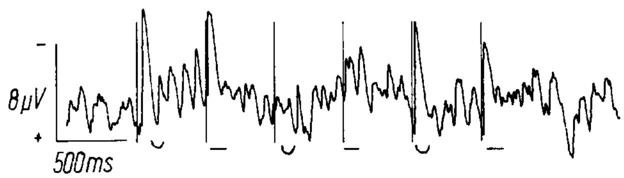

Fig. 4. Iamb modelling: during the light tone before the heavy tone a constantly increasing negativity was visible. The superimposed 10 Hz waves impaired clear recognition of the on effect and were especially pronounced during light tones. Fz, subject 3

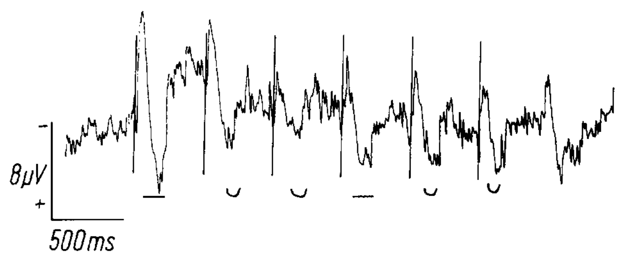

Fig. 5. Only with dactyl modelling was there a positive drop in the underlying DC potential visible between the third and the fourth note. Fz, subject 4

Experiment 2

At the onset of the first tone of the second motif, i.e. shortly before the on effect, a uniform intra-individually reliable positive DC shift measuring 4 µV on average was evident at Fz and Pz in all subjects, resulting in different DC levels for the two motifs (Fig. 6).

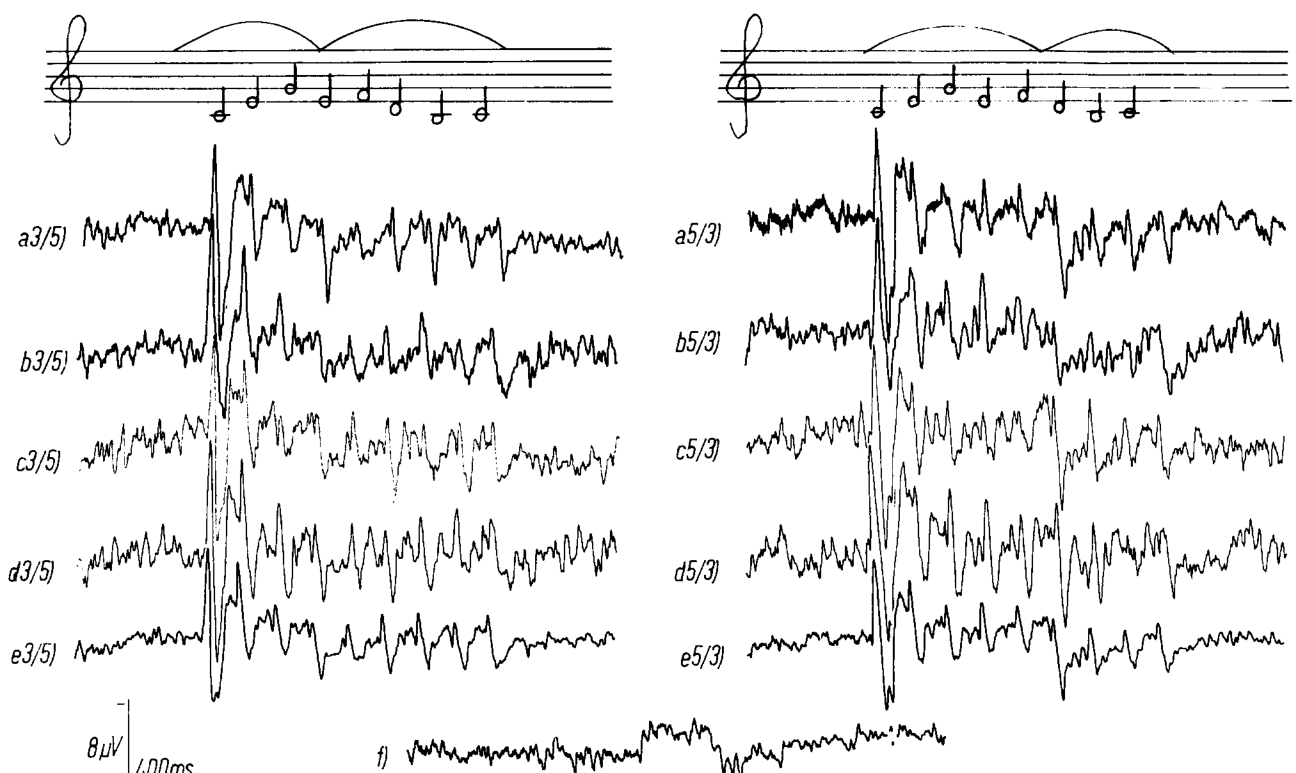

Fig. 6. Experiment 2: For each of the four subjects (a to d) the (3 + 5) tone motif modelling is depicted on the left side, the (5 + 3) tone modelling on the right side, e is the grand average over all subjects and f the subtraction e5/3–e3/5. Note the positive DC shift at the motif border resulting in different DC levels for the two motifs, occurring in each subject. Fz, a to d 150 raw EEGs

Table 1. P2 amplitudes (μV) during first and second motif. For each subject each modelling was calculated twice (i.e. 12 light and 16 heavy tones). Values in parenthesis respresent SDs

	First motif	Second motif
Subject 1	2.0 (0.89)	4.5 (1.48)
Subject 2	1.2 (1.04)	3.2 (0.92)
Subject 3	1.2 (0.88)	4.0 (1.44)
Subject 4	2.9 (0.64)	3.9 (1.51)
Average	1.8 (1.11)	3.9 (1.40)

The P2 amplitudes for individual subjects are depicted in Table 1. No shift was discernible at Oz.

The experiments with modelling simultaneous respiration or movement exhibited movement- and respiration-related potentials which were comparable to those described elsewhere (Grözinger et al. 1974; Deecke and Kornhuber 1977). They were independent of modelling potentials.

Discussion

There have been several investigations of late AEP with musical stimuli in order to study the functional lateralization of the brain hemispheres (Taub et al. 1976; Virág et al. 1979; Shucard et al. 1981); however, these studies were not aimed at elucidating correlations or inter-dependencies between intra-musical patterns and parameters of AEP. Recently Fraisse and Lavit (1986) found a correspondence between N1P2 amplitudes of AEP and the perception of simple rhythmic patterns, which – as opposed to metric patterns – are entirely acoustically determined. At yet, no systematic studies investigating a psychophysiological correlation between modelling activities and evoked potentials have been performed, although some reports dealing with the close relation of late evoked potentials to conscious occurrences have suggested such an influence: for example, a closer resemblance of visual evoked potential waveshapes to anticipated (Begleiter et al. 1973; Buchsbaum et al. 1974) or "hallucinated" (Herrington and Schneidau 1968) stimulus qualities than to factual acoustic stimulus parameters have been demonstrated and cortical slow potentials were observed during acoustic imagery tasks (Brix 1978; Cuthbert et al. 1986).

The results of the present study indicate the marked influence of musical – melodical as well as motifical – "subjective" modelling on late AEP. In each experimental paradigm using evoked potentials, the possibility of modelling mechanisms and subsequent undesirable influences on recordings should be regarded and evaluated to exclude misinterpretations. An example to illustrate possible unwelcome modelling are evoked potentials elicited by an ambiguous word like "fire" showing meaning-related differences, which conventionally are explained by different linguistic processing strategies based on word forms (verb versus noun, Roemer and Teyler 1977), semantic categories (Chapman et al. 1977) or contextual meaning (Marsh and Brown 1977). However, a different meaning often implicates a different rhythmic/metric/dynamic structure (e.g. compare "fire" in "ready, aim, fire" and in "sit by the fire", Marsh and Brown 1977), which may be projected into ambiguous stimuli by the subject, altering the event-related potential. Caution is necessary to recognize motifical modelling influences in slow potential, e.g. in contingent negative variation (CNV) experiments, often consisting of warning and reaction stimuli, which may be regarded by the subject as two separate "motifical" entities resulting in a DC shift between the stimuli as in experiment 2 and in an undesirable interaction with slow potentials to be studied like CNV.

Identification of evoked potential components in experiments 1 and 2 (modelling potentials) with known event-related potential components is difficult. Possible causes of the positivity of the heavy tone in experiment 1 (Fig. 2) could be: positive response component (Otto et al. 1977), P3a (Courchesne 1978), P3b (Rösler 1982), slow wave (Ruchkin et al. 1980) or positivity of sustained potential (Korth and Rix 1979). The following components might be responsible for the negativity in experiment 1 (Fig. 3): processing negativity (Näätänen et al. 1981), mismatch negativity (N200, Näätänen 1981), auditory imagination potential (Brix 1978), negativity of the sustained potential (Picton et al. 1978). There are arguments, regarding each of these components, which contradict identity with modelling components like differences in latency, topography or functional meaning. Myogenic, ocular, respiration or cardiac artefacts were excluded. Also dermal artefacts, caused by changes of skin resistance, were not likely to be the source of modelling potentials, because the skin below the electrode was scratched and the temporal course of the modelling potentials was too rapid. Thus, one has to assume a neuronal source although of unknown origin. However, the identification and exact localization of the neuronal generator of modelling potentials is of secondary importance compared with its practical significance in evoked potential experiments.

Are the modelling potentials correlates of the specific modelling activity of the subject or only of its modelling effort? During difficult tasks P2 latencies are longer than during simpler tasks (Goodin et al.

1983). In both experiments the latencies were constant over tones and subjects. Moreover, in the experiments the effort was constant during the whole stimulus duration, not being different at heavy or light tones or at the first or the second motif; the modelling was, after a time of learning, easy and "automatic" to perform. All this is in accordance with a more specific psychophysiological correlation that indicates possibilities of conclusions regarding the psychological correlate. The inter-individually variable results in experiment 1 and the reliable results in experiment 2 indicate different inter-individual correspondences of meanings of musical terms like metre and motif: motif might be the same phenomenon inter-individually in contrast to metre, which, presumably, is performed by each subject in a different way.

In conclusion there are marked modelling effects on AEP. Additional systematic studies with other modelling activities will uncover the conditions and the intra- and inter-individual reliability of the occurrence of modelling potentials and thus will evaluate its significance as undesirable noise. On the other side evoked modelling potentials could become a fruitful tool in gestalt psychological or music psychological research.

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