IDENTIFICATION OF MUSICAL CHORDS – REACTION TIMES SUPPORT THE ASSUMPTION OF TWO DIFFERENT PROCEDURES

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ABSTRACT

In a speeded decision experiment 10 male and 10 female music students had to distinguish major and minor chords. The chords were played after a short sequence of random tones, a scale and four chords serving the rules of a cadenza (probe tone technique). The now following chord (target) had to be recognized as minor or major as fast as possible. Each subject contributed 2000 correct decisions.

The expected effect could only be observed for major chords following a major prime and with reaction times longer then 450 ms. If minor chords are used either as prime or as target, they seem to change the center of activation.

Because correct decisions with reaction times shorter than 400 ms were not at all systematically affected by the primed tonality, the author considers separate procedures of information processing: A fast pre-attentive procedure and a slower procedure, influenced by expectations evoked by long term memory. These considerations lead to the theory of Pribram (1991), who defined stages of information linked to brain areas: The first stage supplies fast procedures, subcortically and automated – presumably the simple ones as kind of reflexes, the differentiated ones developed by implicit learning. A second stage of information processing is guided by procedures of categorization and chunking, which are affected by remembering and recognition, that means: primed cognitive representations.

1. THEORETICAL BACKGROUND

Harmony and the rules for the progression of chords dominate traditional western music. Within this small sector of the world's music restricted to a period of about 300 to 400 years the cycle of fifth seemes to serve as a tool for the assessement of increase and decrease of tension.

This is described by the theories of Hugo Riemann in his dissertation in 1874. A chord within a piece of music is defined in the context of the three main functions tonic, subdominant and dominant.. This theoretical framework, known as *functional harmony theory* has been further developed by the composers Wilhelm Maler (former director of the music university in Hamburg) and Diether de la Motte (professor at the music universities of Hamburg, Hanover, follower of Heinrich Schenker in Vienna; see Motte, 1976).

Functional harmony theory postulates, that leaving from the harmonical origin of a piece into either direction of the tonal system causes musical tension.

The present author argues, that musical tension arises from the activation of tonal connections: Within a few bars European composers of tonal music establish the system of a well defined tonality. Leaving this tonality into either direction means leaving a familiar surround and causes tension. This increases cognitive workload which should result in prolonged time for the identification of distant musical stimuli (Bruhn, 1988).

International research concerning tonality concentrates on melodies, single tones and intervalls. Often the strength of a connection between musical stimuli has been measured, after a tonality had been activated (for a review see Krumhansl, 1991). They used the so called *probe tone method*: The probe tone (also: *prime*) consisted of a tone, a series of tones or one ore more chords. It is used to activate an imagination of a musical background for the assessment of a hence following musical event as *target* of the experiment – considerably a tone or a chord which had to be rated with respect to similarity or vicinity.

Only a few experiments have been focussed on the assessment of chords and chord sequences. Bharucha and Stoeckig (1986) found, that a major-minor-distinction of chords might be systematically affected by a primed tonality. When asked to decide whether a target chord was in tune or not, the distance between prime and target had a significant influence: Comparing the reaction times of related chords (chords in the surround of the tonic) with unrelated chords (far away by fifths), the decision about in-tune or out-of-tune unrealated chords lasts longer for related in-tune chords.

Justus and Bharucha (2001) stated the former result, but found an interaction between the type of chords and the reaction time: misstuned chords accelerate the reactions, while the distance prolongs the times (see fig. 1).

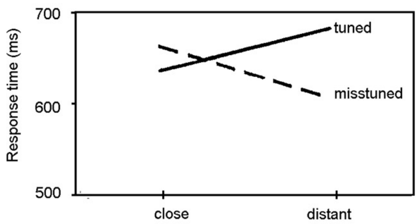

Fig. 1: Time to detect whether a chord is in or out of tune (adapted from Justus & Bharucha, 2001, p. 1502).

The present experiment will try to reconfirm and to refine these results. Preceeding research show the expected direction of influence – but the studies are not very precise: They distinguish between far and near chords, which is not enough for musical analysis. In another text Bharucha announced results of all fifths of the cycle of fifth – but these data never were published.

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2. AIMS OF THE EXPERIMENT

2.1. Hypothesis

The difficulty of recognizing chords as minor or major is changing with the tonal context, in which the chords are heard. The time for a correct recognition of major and minor is dependant on the distance from a primed tonal surround of the chord. The distance is measured in fifth, according to the cycle of fifth (see fig. 2), which indicates the distance between two tonalities. The more fifths lie between the primed tonality and the target chord, the more time should be necessary to decide about the type of the heard chord.

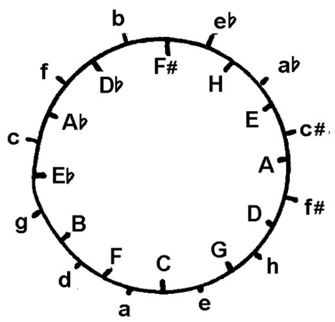

Fig. 2: Cycle of fifths, respectively cycle of thirds, when including the minor keys; it determines the distance between a primed tonality and a target chord (Bruhn, 1988).

2.2. Design of the experiment

The experiment was controlled by a pascal program (Delphi 6.0) using a laptop and a sound modul (Roland JV-1010) via MIDI. The program was designed to play all combinations between major and minor prime and target with respect to the distance of the target chord (which had to be recognized) and the primed tonality. The program began with a sequence of six tones at random hight, followed by a major or minor scale and four chords, a cadenza I–IV–V–I, played in six different ways). This scale together with the four chords of a cadenza will be called prime.

After a short break a chord is played, which had to be recognized as minor or major by pressing the left or right arrow-key of the laptop-keyboard – the meaning of the keys (major or minor) has been randomized from day to day. This chord will be called *target*.

The program determines mode of prime and target and finds the distance between both (everything by random). A set of all possible connections were played to the subject – 48 different pairs of prime and target with major, minor and 12 fifths as possible distances.

After having answered these 48 chord connections correctly, another set of 48 pairs are presented.

Time was measured from the end of the MIDI-on signals of the target chord til the moment, when WIN 98 took notice of the keypress.

3. RESULTS

All subjects were students of the Hamburg Music University (table 1: subject 10 to 19 male; 20 to 29 feemale). The students were participants of ear training courses and had been recommended as advanced students. The experiment had been completed by each subject within two weeks, which resulted in a participation of nearly one hour each day.

3.1. Mean RT (reaction time) from all subjects

When considering all correct responses unweighted, the hypothesis has to be rejected. The distance in fifths does not have the predicted influence on RT. The data show considerable differences between the 48 conditions of the experiments, all of them significant. But the structure of the reaction times does not show any dependencies at all, that would support the prelimenary hypothesis.

Amazingly half of the subjcets performed so well, that between 11 and 38 percent of their RT where faster than 400 ms (tab. 2). The 1 % significance level for the shortest RT above chance was 330 ms (shortest RT over all 266 ms).

Sub. No.	chords in total	chords correct	correct %	RT<400 in %		1 % sig. lower level
10	**2212**	**2000**	**90,4**	**531**	**26,6**	**330**
11	**2175**	**1924**	**88,5**	**222**	**11,5**	**370**
12	2215	2002	90,4	13	0,6	440
13	2069	2000	96,7	35	1,8	380
14	1963	1920	97.8	0	0	520
15	**2135**	**2016**	**94,4**	**225**	**22.3**	**360**
16	2231	2050	91,9	170	8,3	380
17	**2163**	**2016**	**93,2**	**351**	**11,4**	**360**
18	2067	2016	97,5	98	4,9	370
19	**2077**	**2000**	**96,3**	**260**	**13,0**	**360**
20	**2496**	**2030**	**81,3**	**775**	**38,2**	**330**
21	2060	2016	97,6	167	8,3	340
22	**2215**	**2016**	**91,0**	**439**	**21,8**	**340**
23	2158	2000	92,7	147	7,4	370
24	2106	2016	95,7	1	0,0	450
25	**2046**	**2000**	**97,8**	**421**	**21,1**	**350**
26	**1863**	**1824**	**97,9**	**216**	**11,6**	**360**
27	2037	2000	92,2	27	1,4	395
28	**2187**	**2016**	**92,2**	**371**	**18,4**	**345**
29	2229	1880	84,3	23	1,2	410
sum	42704	39742		4492		

Tab. 1: Total and correct identifications of minor/major for all subjects, followed by the number of RT < 400 ms and 1 % significance-level.

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These fast RT seemed to be unrealistic, because a conscious reaction to a percieved stimulus needs 250-300 ms to exhibit a typical potential in the cortex (Tervaniemi, 2001, p. 268): N2b and P3b seem to reflect cognitive processes concerning attentive processing. Adding 150 ms as minimum for a conscious motor reaction (Slater-Hamel, 1960) means, that a conscious decision between major and minor must not be faster than aproximately 400 ms.

So the author decided to visualize the fast RT. Surprisingly the data approach the distributions in figure 3, when the short reaction times are extracted gradually in 10ms-paces from the data.*) A systematical influence of the induced tonality and mode seems to be obvious. But only when prime and target are major, the predicted prolonged reaction time could be found – each fifth distance causes a prolongation of about 5-10 ms. All other reaction time distributions have a deviant minimum:

- Major target, prepared by minor prime: two fifth below the center of the priming tonality – that means in terms of harmony theory the dominant of the parallel major key (e.g. B-major/E-flat-major in the priming tonality c-minor);
- Minor target, prepared either by minor or major prime: three fifth below the center of the priming tonality – a chord, which is not explicable in harmony theory (e. g. e-flat-minor compared with a priming tonality of c-minor).

The prime shows a remarkable effect, which offers declarations, although they lead to a new set of hypothesis (see below). Small areas show inconsistent changes between adjacent distances. These areas of inconsistent RT lie in the far distance from that stimulus condition which exhibits the fastest reaction time.

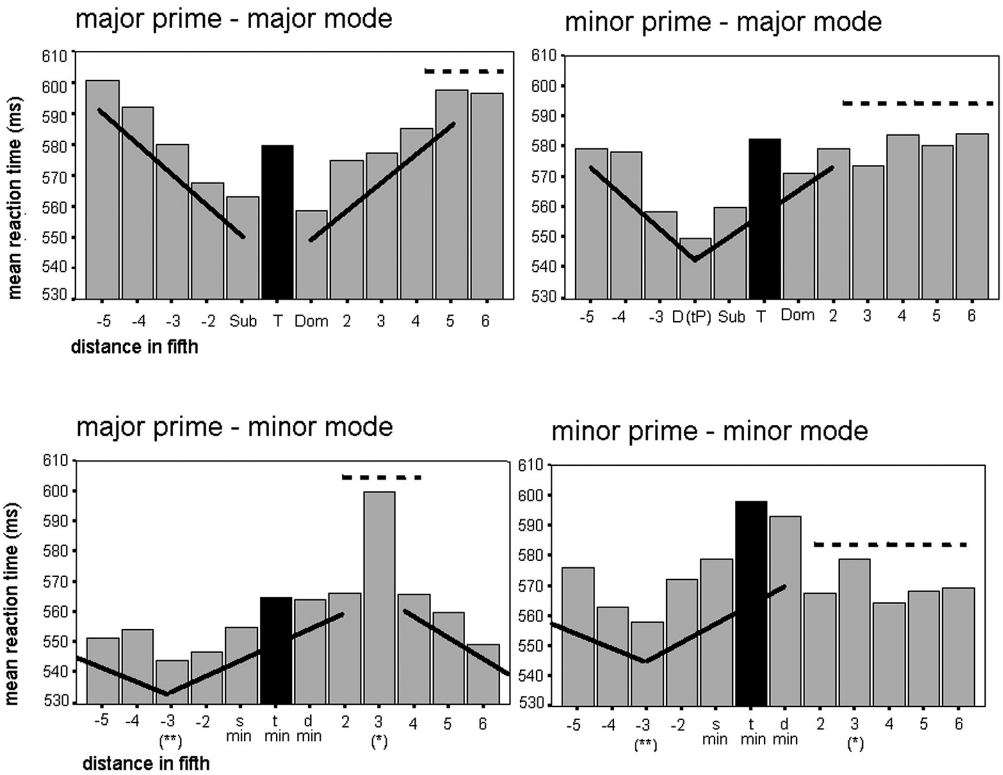

Fig. 3: The charts show mean reaction times of all correct responses of the 20 subjects, excluding the fast reactions < 450 ms. T means that the same chord (tonic) followed the prime as target. Dom = Dominant, Sub = Subdominant, 2 = two fifths up, -2 = two fifths down etc. Double asterisk: Center of activation for minor targets 3 fifths below the tonic. Black column tonic prolongation; similarly the parallel of the tonic (one asterisk). Dotted: the far distances around the 6th fifth.

3.2. Reaction times of the fast decisions

Figure 3 shows the RT below 450 ms. The confidence interval becomes narrow, because the variance dimishes rapidly. The differences between the chord sequences vanish – it looks as if the reaction times are no more dependent of the priming tonality and the distance between prime and target.

That is astonishing, because the shorter RT cover still about one third of the whole data. The small variance within and bewteen the 48 conditions are not due to a small number of cases: 29,9 percent = 11.877 pairs of prime and stimulus were left (tab. 2).

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ms	< 400	401-450	> 450	total
N %	4.492 11,3	7.385 18,6	27.865 70,1	39.742 100

Table 2: Percentage of fast responses.

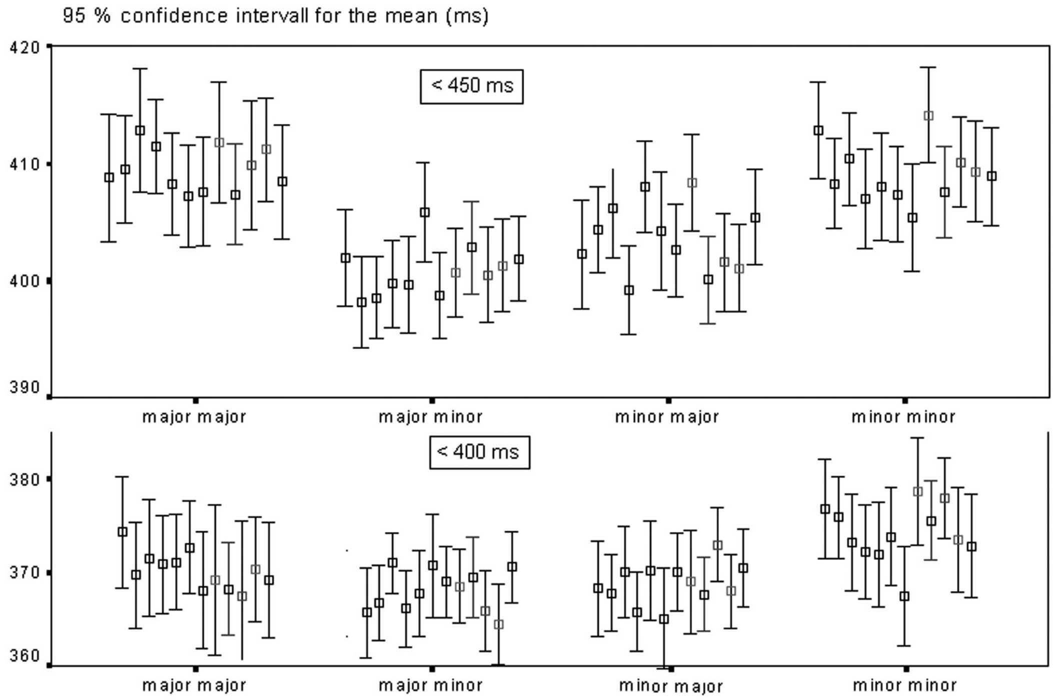

Fig. 4: Confidence interval (95 %) of the reaction times slower than 450 ms. The four modes of prime-target combination form clusters – within the clusters the reaction times vary in a small range of less than 10 ms without any explainable relation to the tonal context.

4. DISCUSSION

The results were not expected, but nevertheless interesting.

- Possibly there must be distinguished between two types of information processing: A fast one, possibly preattentive and automated RT is not affected by the priming tonality. This would be in consent with the theory of Pribram (1991), who separated sensory from cognitive processing (see abstract above).
- Only the longer type of information processing is affected by the prime – perhaps priming needs access to explicit representations of learnt tonal structures.
- The prolongation of the tonic and its parallel could be interpreted this way: Wellknown or expected stimuli cause an interaction between priming and hesitation.
- Higher order distances seem to cause confusing RT (see dotted lines in fig. 4). Perhaps this is a consequence of information processing limits, caused by too great difficulties in processing the distances between prime and target.

Research should now be conducted in to two directions: (1) Neuroimaging procedures would be able to locate the difference between the two modes of information processing found in this experiment. (2) Musicological inquiry should try to find out more information about the interdependence between major and minor.

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