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CATEGORIZATION, RATING AND DISCRIMINATION OF MUSICAL CHORDS

This paper is an interim report of a study that we have been doing together with Åke Hellström from the University of Stockholm and Heikki Lang from the University of Turku and many others mainly in the Cognitive Neuroscience Unit of Turku. The central aim of the study is to compare vowel perception with the perception of musical stimuli. In this paper we present some results of experiments in identification, rating and discrimination of musical chords and some preliminary observations on their electrical responses on the cortex. It seems that chords which vary between major and minor are perceived in many cases in the same way as phonemes of a language, but there are also differences which may be due to the categorical nature of musical stimuli.

Introduction

Musical stimuli have been used for long as controls in the study of speech perception. According to this approach, the pattern of discrimination functions on a speech continuum is compared with that on a nonspeech (e.g., musical) continuum resembling it (e.g., Pisoni 1977). If similar discrimination patterns are observed, then both sets of data are assumed to result from a common process, not specific to speech. For example, categorical perception was once assumed to be specific for speech (Liberman, Harris, Hoffman, Griffith 1957) until categorical effects on musical continua were observed (Cutting 1982).

P. K. Kuhl (1991) provided the first evidence suggesting that discrimination is affected not only by the acoustic factors but also by stimulus typicality. She showed that a vowel judged to be a prototype of its category was more difficult to discriminate from its neighbors than a less prototypical one. She suggested that in respect to discrimination, the prototype acts like a ”perceptual magnet” by pulling other stimuli toward itself and by that means it strengthens category coherence. P. K. Kuhl (1991) suggested that the magnet effect for vowels, which was found only in human beings and not in animals, must reside at the phonetic stage, subsequent to the auditory analysis. The study of O. Aaltonen, O. Eerola, Å. Hellström, E. Uusipaikka and H. Lang (1997) tested this hypothesis by employing psychophysiological recordings (MMN) in addition to behavioral measures. Their results show that individual listeners are inconsistent in categorization and goodness rating but consistent in discrimination. For all the subjects, the poorest discrimination occurred at about the same location in the F2 continuum, but only the data from the good categorizers can be explained as resulting from a prototype-based magnet effect. The MMN recordings yielding the same results suggest that linguistic experience can alter the basic sensitivity of acoustic analyzers below the level of controlled and conscious perception. A recent crosslinguistic study of R. Näätänen and his colleagues (1997) gives further support for the view that there are language-specific vowel representations in the left auditory cortex, and that these experience-dependent neural memory traces can be revealed by the MMN paradigm.

The present study consists of the same experiments (categorization, goodness rating, discrimination and MMN recordings) as that of O. Aaltonen, O. Eerola, Å. Hellström, E. Uusipaikka and H. Lang (1997).

The musical items chosen for the study were the major and the minor triads, because they can be thought of as categories in many ways similar to vowels; they depend on the relationships between their components, not on any absolute pitch levels. There is also a musicological interest in the study; the two triads are considered equally worthy categories by many musicologists whereas many say that the minor chord is only a deteriorated form of the major chord. Jouko Tolonen (1969) made an extensive study of the question, but did not give a definitive answer.

The difference between the major and the minor chords is that the middle note in the major chord is higher than in the minor chord. Both chords can be found in the harmonics of a single complex tone. The fourth, fifth and sixth harmonics form a major triad, but for the minor chord we have to take the tenth, twelfth and fifteenth harmonics. Thus the ratios of the notes that form these triads are 4:5:6 for the major and 10:12:15 for the minor triad. Sine waves with these ratios do not form chords, only complex tones whose fundamental frequencies have these ratios do. When the notes of a chord have these ratios the resultant chords are called natural, because at least their fundamentals can be traced back to the harmonic series. In today's music we do not always hear naturally tuned chords, because for certain practical reasons the octave has been divided in twelve equal intervals, which means that many notes are slightly off pitch. In this, the so-called tempered system the middle note of a major chord is higher and the respective note of the minor chord lower than in natural tuning. In our study we also hoped to see if the difference between natural and tempered chords could be discerned.

The experiments

For the experiments a series of chords was synthesized on a Yamaha TX81Z synthesizer using vibraphone like tones. All chords had the lowest note at 440 Hz (A4) and the highest note at 660 Hz (E5). The middle note was varied between 520 Hz (a little below C5) and 560 Hz (a little above C#5) in equal steps of 4 mel for the identification, the rating and the discrimination tests, and for the discrimination tests also differences of 8 mel were used. The 4 and 8 mel differences were used also for the MMN (mismatch negativity) tests to determine how the brain reacts to these stimuli.

In the identification test 53 students either of the Conservatory of Turku or the University of Turku were asked to identify the chords of the series (15 repetitions of 20 different chords in random order) as major or minor by pushing one of two buttons connected with the computer that kept score of the answers.

In the rating task 14 of the better identifiers were asked to rate the same series for the goodness of the chords as minor or major using a scale from 0 to 7.

In the discrimination test 45 of the original 53 subjects were asked if a pair of chords they heard were the same or different. 168 pairs (7 repetitions of 24 pairs in random order) representing different points of the major-minor continuum were presented. The middle notes in the pairs differed by 8 or 4 mel or were the same.

20 subjects (10 good and 10 poor categorizers) have also participated MMN recordings in which standard and deviant stimuli from the discrimination test were used in an ignore condition, which does not require conscious responses from the subject.

Results

The results of the identification tests are fairly interesting. As expected, there were some subjects who simply could not distinguish between the two chord categories. On the other hand, there were many who made a sharp distinction between two kinds of chords with a narrow in-between area. Musically it is interesting that the good categorizers seem to have been consistent with so many chords that have really false notes. At least we have found a clear boundary between the two categories. We have chosen to present the identification answers of Subject 13 in Figure 1 as examples of a strong categorizer. She is suspected of being highly musical, but no musicality tests proper were made.

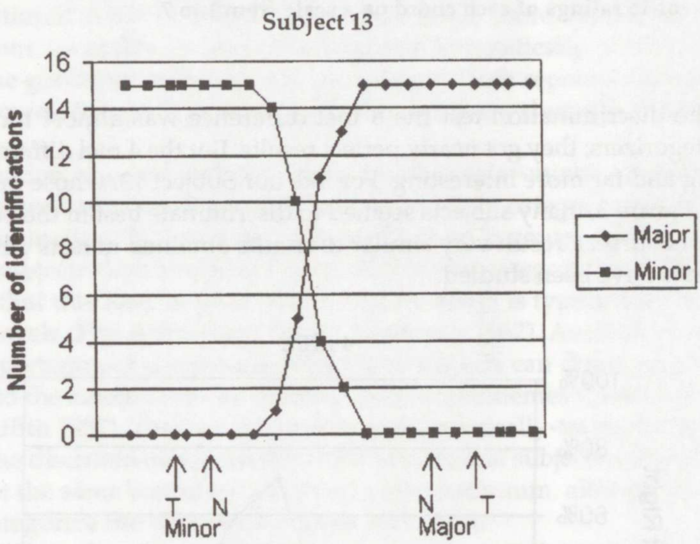

Figure 1. **Identification of the test chords as either minor or major by Subject 13, a good categorizer. The pitches of the middle notes rise from left to right on the x-axis and the pitches of the tempered (T) and the natural (N) chords are marked with arrows.**

The results of the rating test changes the picture somewhat. The chords that are in the no man's land get poor ratings whichever way they are interpreted. The best ratings were generally given to chords in the area of the natural and the tempered chords, but they did not always hit the musically best chords. For example, our Subject 13, whose ratings are shown in Figure 2, gave the best ratings to chords around the natural major chord but favored the tempered minor chord, and not quite as surely as the major.

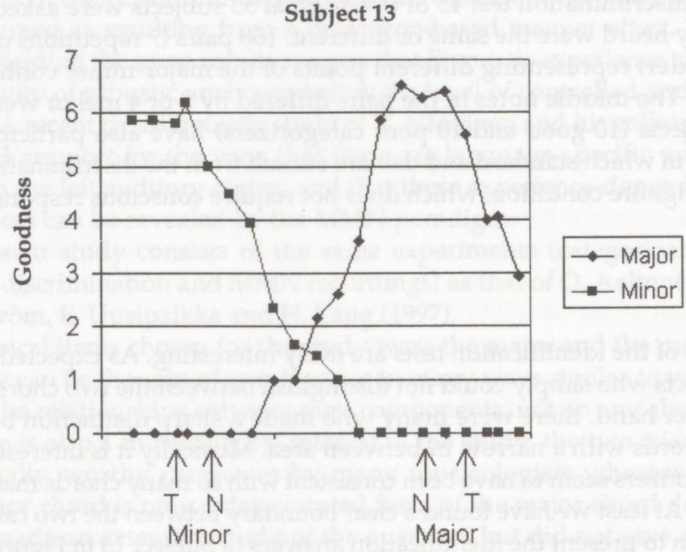

Figure 2. **Goodness rating of the test chords as minor or major by Subject 13. The x-axis is the same as in Figure 1. The goodness on the y-axis represents the averages of 15 ratings of each chord on a scale from 1 to 7.**

In the discrimination test the 8 mel difference was almost too easy for the good categorizers; they got nearly perfect results. But the 4 mel difference was more revealing and far more interesting. For like our Subject 13, whose percentages are given in Figure 3, many subjects seemed to discriminate best in the boundary area. This is, of course, a result very similar to results obtained in tests where phoneme boundaries have been studied.

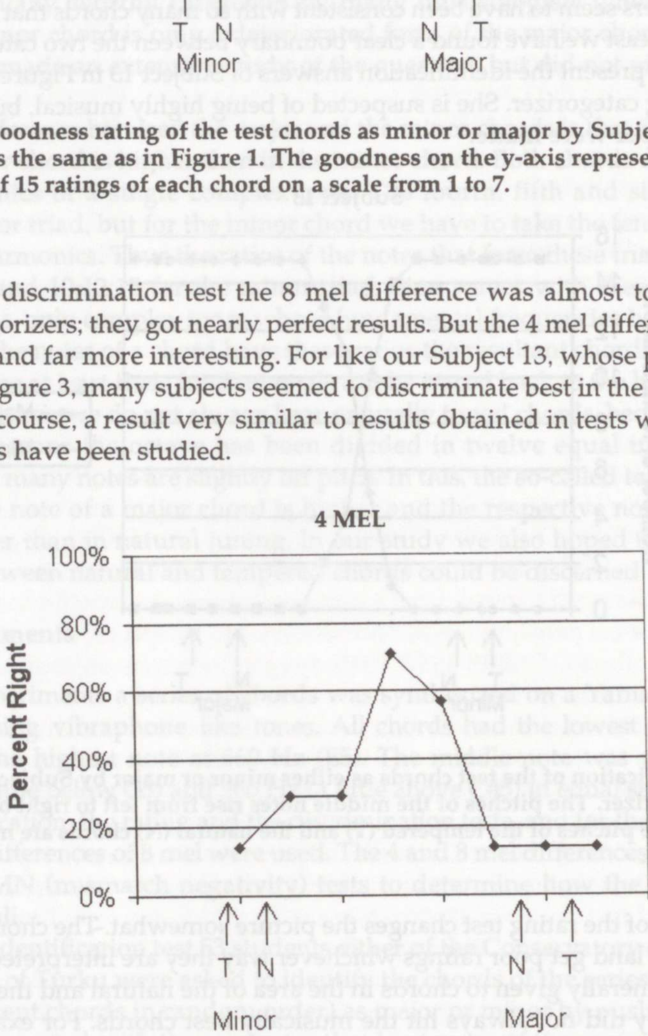

Figure 3. **Discrimination of two chords with a difference of 4 mel in the middle note by Subject 13. The x-axis is the same as in Figure 1.**

For good categorizers the MMNs were larger than for the poor categorizers, which also correlates with their discrimination performance. In addition, equal mel-differences elicited different MMNs depending on the location of the deviant on the major-minor continuum. The MMNs were larger within the minor than within the major categories. Contrary to the discrimination data, no clear boundary effect was obtained. For all the subjects, the MMNs were the smallest close to the natural major and increased towards both ends of the continuum. However, the poor categorizers showed also another location of decreased MMN within the minor category, which was not observed in the MMN data of the musically trained subjects.

Conclusions

Those test subjects who categorized consistently along the minor and major continuum did so in the same way as Finnish subjects categorizing the F2-continuum, for example into /i/ and /y/. The width of the boundary varied interindividually but its location was quite stable (almost in the middle of the continuum). This is different from the perception of vowels where location of the boundary is not so stable. The same vowel sound can be categorized differently by speakers of one language. Subjects with no musical training, could not label the stimuli consistently as minor or major. Only a few of the musical subjects could rate the goodness of the stimuli. The stimuli in the vicinity of the natural major chord were rated by them as the best. Thus, an ability to categorize does not automatically predict an ability to evaluate the goodness of the stimuli according to their representativeness of a category. In vowel tests, on the contrary, good categorizers always rated the vowels consistently.

Discrimination of equal mel differences on the major-minor continuum was best by the subjects who could identify the chords. Poor categorizers showed the poorest discrimination. The same result was obtained in vowel perception. However, all the subjects discriminated better around the category boundary. It has been argued that this kind of phoneme boundary effect is typical for consonants but not for vowels (Fry, Abramson, Eimas, Liberman 1962). According to the traditional interpretation of categorical perception subjects can discriminate speech sounds only to the extent they can identify them as phonemes (Liberman, Harris, Hoffman, Griffith 1957). This is evident only in the musically-trained subjects. It is strange that the discrimination patterns of the nonmusical subjects show better discrimination at the same boundary location in the continuum, although they were not able to categorize the chords into major and minor.

The MMN data show larger MMNs for the good categorizers than for the poor ones corresponding to the discrimination performance of the subjects. The same result has been obtained with vowels. For all the subjects the MMNs were the smallest for the stimuli close to the natural major, which were also rated by the musically trained subjects as the best (the prototype of the major category). This seems to speak for a greater naturalness of the major triad over the respective minor chord.

As this paper shows we have found more similarities than differences in the perception of musical chords and vowels. Some of this can probably be explained by the fact that all of us have extensive training in language but not all of us have any training in music. A deeper analysis of the results of these experiments will be published later.

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