Emotion Processing of Major, Minor, and Dissonant Chords

A Functional Magnetic Resonance Imaging Study

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ABSTRACT: Musicians and nonmusicians listened to major, minor, and dissonant musical chords while their BOLD brain responses were registered with functional magnetic resonance imaging. In both groups of listeners, minor and dissonant chords, compared with major chords, elicited enhanced responses in several brain areas, including the amygdala, retrosplenial cortex, brain stem, and cerebellum, during passive listening but not during memorization of the chords. The results indicate that (1) neural processing in emotion-related brain areas is activated even by single chords, (2) emotion processing is enhanced in the absence of cognitive requirements, and (3) musicians and nonmusicians do not differ in their neural responses to single musical chords during passive listening.

KEYWORDS: emotions; music; musical competence; working memory; emotion–cognition interaction

INTRODUCTION

Major, minor, and dissonance in music are commonly said to cause happy, sad, and unpleasant experiences, respectively. Behavioral studies have shown that these emotional effects may be elicited by brief melodic fragments and even by isolated chords in musicians as well as nonmusicians.[1] Dissonance presented in melodies was previously related to activity in the right parahippocampal gyrus and right

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precuneus brain areas.[2] Moreover, the downregulating effects of appraisal and cognition on emotion processes were demonstrated in terms of amygdalar responses to aversive visual stimuli.[3] In spite of the well-proven power of music to elicit positive or negative emotional experiences, the mechanisms for emotional regulation have not so far been studied in this domain. Because musical competence, reflected in the neurophysiological auditory responses, implies a more analytical approach to musical sounds, this may also reflect in the neural emotion processes. We studied whether (1) simple musical chords activate brain areas previously associated with emotion analysis, (2) cognitive evaluation has an influence on these responses, and (3) musical competence influences the emotional responses.

METHODS

Twenty-one right-handed individuals (mean age 26; 14 females), 11 subjects with a classical music education (musicians), and 10 subjects with no musical training (nonmusicians), were subjected to nine piano chords belonging to three pitch classes (major, minor, dissonant), each spanning three octaves from A3 to A5. The subjects either listened passively to the chords or performed an n-back working memory task with respect to pitch. After the brain scanning, the subjects were asked to rate the emotional connotations of each chord on two 11-point scales (as unpleasant-pleasant and sad-happy, respectively). In all conditions, subjects pressed a button after each chord to maintain motor-related brain activity constant across conditions. Magnetic resonance images were acquired with a 1.5-T Siemens Sonata scanner. Analysis was performed using FMRIB Software Library (FSL, Oxford, UK). Each subject's structural and functional data were coregistered to the MNI152 standard template.

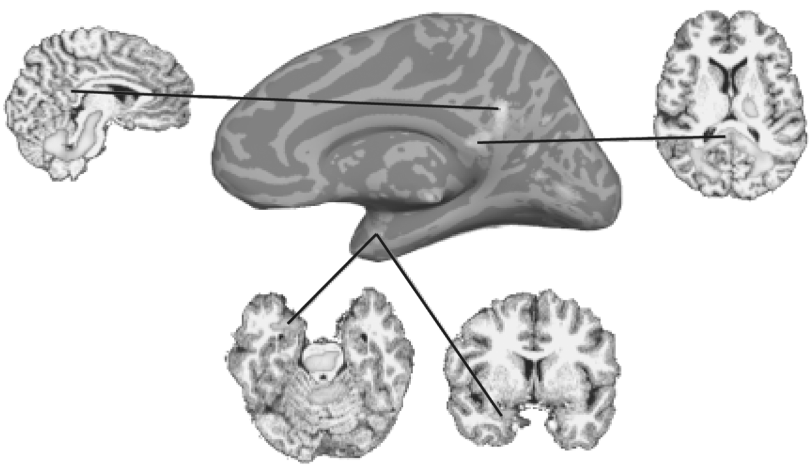

FIGURE 1. BOLD responses that were larger during passive listening to minor chords than during passive listening to major chords, including the amygdala, retrosplenial cortex, brain stem, and cerebellum. The responses in this contrast were not present during working memory. Group results are overlayed on transverse sections and inflated cortex of a single individual (corrected for multiple comparisons: $Z > 3$, $P < .05$).

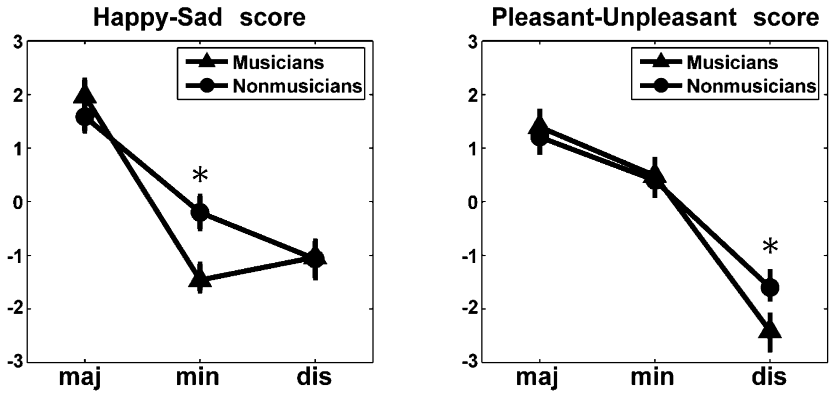

FIGURE 2. Emotional ratings (mean ± SE) of major, minor, and dissonant chords. Musicians rated dissonant chords as significantly more unpleasant, and minor chords as significantly more sad than nonmusicians did (*$P < .05$).

RESULTS

During passive listening, minor and dissonant chords elicited larger BOLD responses than did major chords in several brain areas, including the amygdala, retrosplenial cortex, brain stem, and cerebellum (FIG. 1 represents the minor versus major chords contrast). Together with the thalamus and brain stem, the amygdala has been implicated in the evolution of an adaptive "alarm system."[4] These differential responses to minor and dissonant chords, compared with major chords, were not present during the pitch working memory task, requiring cognitive evaluation of the chords. Although musicians rated minor chords as sadder and dissonant chords as more unpleasant, than did nonmusicians (FIG. 2), there were no significant differences between the two groups of subjects in the neural responses to the chords during passive listening.

CONCLUSION

The results provide evidence for a role of emotional reactions to isolated musical sound units in the musical experience. Moreover, they confirm that cognitive evaluation leads to decreased emotional responsiveness. We suggest that the amygdala–brain stem responses, during passive listening, to minor and dissonant chords, compared with major chords, reflect a mechanism that automatically interprets these chords as being potentially alarming stimuli. The group difference in the emotional ratings of the chords, but not in the neural responses, may reflect a musician's ability to recognize and categorize the chords in terms of the conventional emotional connotations, rather than an effective enhanced emotional experience.

[Competing interests: The authors declare that they have no competing financial interests.]

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