Biological Psychology 85 (2010) 393–409

Contents lists available at ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Cognitive vs. affective listening modes and judgments of music – An ERP study

Elvira Brattico[a,b,*], Thomas Jacobsen[c,d], Wouter De Baene[e], Enrico Glerean[a,b], Mari Tervaniemi[a,b]

[a] Cognitive Brain Research Unit, Institute of Behavioral Sciences, University of Helsinki, Finland
[b] Finnish Center of Excellence in Interdisciplinary Music Research, Department of Music, University of Jyväskylä, Finland
[c] Institute of Psychology I, University of Leipzig, Germany
[d] Experimental Psychology Unit, Helmut Schmidt University/University of the Federal Armed Forces, Hamburg, Germany
[e] Department of Experimental Psychology, Ghent University, Belgium

ARTICLE INFO

Article history:
Received 23 January 2009
Accepted 31 August 2010
Available online 17 September 2010

Keywords:
Event-related potential (ERP)
Music perception
Late positive potential (LPP)
Early right anterior negativity (ERAN)
Judgment processes
Aesthetics
Liking
Musical preference

ABSTRACT

The neural correlates of processing deviations from Western music rules are relatively well known. Less is known of the neural dynamics of top-down listening modes and affective liking judgments in relation with judgments of tonal correctness. In this study, subjects determined if tonal chord sequences sounded correct or incorrect, or if they liked them or not, while their electroencephalogram (EEG) was measured. The last chord of the sequences could be congruous with the previous context, ambiguous (unusual but still enjoyable) or harmonically inappropriate. The cognitive vs. affective listening modes were differentiated in the event-related potential (ERP) responses already before the ending chord, indicating different preparation for the judgment tasks. Furthermore, three neural events tagged the decision process preceding the behavioral responses. First, an early negativity, peaking at about 280 ms, was elicited by chord incorrectness and by disliking judgments only over the right hemisphere. Second, at about 500 ms from the end of the sequence a positive brain response was elicited by the negative answers of both tasks. Third, at about 1200 ms, a late positive potential (LPP) was elicited by the liking judgment task whereas a large negative brain response was elicited by the correctness judgment task, indexing that only at that late latency preceding the button press subjects decided how to judge the cadences. This is the first study to reveal the dissociation between neural processes occurring during affective vs. cognitive listening modes and judgments of music.

1. Introduction

Listening to music involves several processes of cognitive, evaluative and affective natures. As a consequence of everyday exposure to music even individuals without any formal music training are able to implicitly encode the structures and properties of tonality and harmony which underlie most musical genres of Western culture, like popular and classical music (Tillmann et al., 2000). The implicit encoding of those musical properties leads to the formation of expectations for the incoming sounds. If those expectations are broken, i.e., if the incoming sounds are incongruous with the previous context, affective sensations of tension are generated. Tension is released once expectations are fulfilled, resulting in affective sensations of relaxation (Meyer, 1956). The cognitive reactions to musical incongruity have been extensively measured by asking subjects to rate the congruity of sounds with the previous context (Krumhansl, 1990).

Various brain-imaging techniques have also been used recently to record the online responses of the brain of healthy subjects to violations of musical properties (Besson and Schön, 2003; Brattico and Tervaniemi, 2006; Brattico, 2006; Koelsch et al., 2000; Patel et al., 1998). Several studies using the event-related potential (ERP) technique converged in identifying a family of early neural responses elicited at around 200 ms after a musical rule violation, including the early right anterior negativity (ERAN), and the mismatch negativity (MMN). In electrical recordings, these brain responses consist of voltage changes over the scalp and appear as negative deflections of the ERP commonly peaking at frontal scalp regions. Typically the MMN is elicited by local violations of scale properties (e.g., unconventional intervals between tones), and is generated mainly in the auditory regions of the right temporal lobe (Brattico, 2006; Leino et al., 2007). In contrast, the ERAN is elicited by unusual chord successions violating hierarchical rules of Western tonal harmony and it is generated mainly in the bilateral prefrontal lobes (Koelsch and Siebel, 2005; Koelsch et al., 2000; Leino et al., 2007; Steinbeis et al., 2006; for a discussion about differences and similarities between the ERAN and MMN, see Koelsch, 2009). ERP responses occurring at

* Corresponding author at: Cognitive Brain Research Unit, Institute of Behavioral Sciences, P.O. Box 9, 00014 University of Helsinki, Finland.
Tel.: +358 44 373 3297; fax: +358 9 191 29450.
E-mail address: elvira.brattico@helsinki.fi (E. Brattico).

0301-0511/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.biopsycho.2010.08.014

earlier latencies, such as the N100 peaking at around 100 ms from sound onset, may also be modulated by musical properties; however, the related brain evidence is comparably scarce and not fully convergent (Krohn et al., 2006; Kuriki et al., 2005; Tervaniemi et al., 2003).

Another important group of brain responses identified in association with musical rule violation consists of late long-lasting positive potentials of large amplitude peaking at around 300 ms, and thus named P300, or at around 600 ms, and thus termed P600, from stimulus onset (Besson and Schön, 2003; Brattico and Tervaniemi, 2006; Brattico, 2006). Differently from the ERAN and MMN elicited under semi-active or totally passive experimental conditions, the P300 and P600 are obtained only under experimental conditions in which subjects are attending to the sounds and performing a task related to them. These late brain responses are hence supposed to reflect the conscious cognitive processing of a deviation from musical expectations formed on the basis of the previous context, and the context updating for the subsequent incoming sound events. Nevertheless, the issue whether brain responses to harmonic or melodic incongruity are stable across subjects or variable across individuals has been largely neglected in the MMN, ERAN or P600 literature (apart from effects of musical expertise) since those ERP responses have been typically computed regardless of the subjects' behavioral ratings of tonal correctness.

Listening to music not only involves the cognitive processes, which most frequently attracted the attention of music neuroscience researchers (see above), but evaluative and affective processes as well (see Peretz and Zatorre, 2003). Listeners unconsciously assess the quality of the music heard according to a positive or negative value, on the basis of properties related to the music itself, such as formal structure, beauty, harmonic congruousness, and also based on individual characteristics of the listener, such as attitudes, personality, motivation and prior knowledge (e.g., North and Hargreaves, 1997a,b). One simple type of evaluative judgment is represented by liking: along with processing the perceptual, affective and formal contents of a musical piece, listeners assess how much they like or dislike the piece. Liking judgment is typically accompanied by a hedonic sensation, which in aesthetic contexts is mainly conscious to the subject (Berridge and Robinson, 2003; for discussions of liking within the musical context, see Brattico and Jacobsen, 2009, forthcoming). Dissociations between affective and cognitive ratings of music have been hinted at. In a behavioral experiment using the dichotic listening procedure, one group of subjects judged whether melodies sounded correct or not and a second group of subjects judged whether the same melodies sounded pleasant or not. The results showed that pleasantness ratings of melodies predominantly involved the right cerebral hemisphere, as indicated by the left-ear preference, whereas no brain lateralization occurred during correctness ratings (Gagnon and Peretz, 2000). Distinct neural mechanisms for affective vs. cognitive processing of music were also suggested by neuropsychological evidence of a patient with bilateral temporal lobe lesions having preserved music emotion and appreciation combined with disrupted perceptual musical abilities (Peretz et al., 1998).

In other sensory modalities, researchers have explored the relation between liking judgments and cognitive descriptive ones. For instance, the liking judgments of words were delayed as compared to the lexical decision ratings of the same words (Mandler and Shebo, 1983). Similarly, the evaluative ratings of paintings were slower than judgments of prior encounters of the same stimuli (Mandler and Shebo, 1983). Thus, liking seems to require more complex and resource-demanding processes than knowing, suggesting that those two different processes may be independent from each other. A subsequent study involving behavioral ratings of visual geometric abstract black and white pictures as well as electrophysiological recordings confirmed that evaluative processes in the visual domain are relatively slow, and, in part, occur later than descriptive processes (Jacobsen and Höfel, 2003). Fast and slow routes to affective evaluative processes have been hypothesized (Scherer and Zentner, 2001). The fast primary route to the positive (or negative) appraisal or evaluation of an event relies on the quick and automatic brain responses. Those responses are below the level of consciousness and likely originate in the brainstem and primary sensory cortices. The slow responses, instead, occur mainly in the evolutionarily more recent structures of the brain, such as the prefrontal cortex, and lead to the conscious appraisal and liking of a piece of art or an everyday object (Jacobsen et al., 2006). In sum, the results obtained with visual or linguistic stimuli call for further investigation of the interrelation between cognitive and evaluative processes also in the musical domain.

The ERP method allows one to determine the dynamics of information processing in the cerebral cortex by analyzing the main voltage changes time-locked to the stimulus or task of interest (Luck, 2005). In our experiment, as a first main aim, we were interested in determining whether a top-down affective vs. cognitive listening mode adopted during two judgment tasks would by itself modulate the sensory processing of sounds even before the judgment decision. As a second main aim, we wished to investigate whether different sub-processes involved in assessing the liking vs. the tonal correctness of the same musical material would be reflected in the electric brain responses. Finally, as a third exploratory aim, we wished to assess the amount of variability and subjectivity in affective and cognitive judgments of music and in their underlying neural mechanisms.

According to the valence lateralization model, positive emotions are controlled by the left-hemispheric frontal cortex, whereas negative emotions rely on the intact functioning of the right-hemispheric frontal cortex (Davidson, 1993; Fox, 1991; for supporting results with musical stimuli, see Altenmüller et al., 2002; Flores-Gutierrez et al., 2007; Gagnon and Peretz, 2000; Schmidt and Trainor, 2001). We hence hypothesized that the holistic mental strategies of affective vs. cognitive modes of listening to music would modulate the amplitude and lateralization of the early auditory-cortex responses to each chord already before the time of judgment decision. We further predicted that the affective component of the liking judgments, i.e., the associated hedonic enjoyment of the listened music, would be reflected in the lateralization of the brain responses. Moreover, we expected to obtain enhanced late positive brain responses to liking judgments similarly to what was found in other sensory modalities and cognitive domains. Specifically, a late positive response termed the late positive potential (LPP) was elicited during the performance of evaluative classification of faces, visual art, objects, words, and similar (e.g., Cacioppo et al., 1994; Crites et al., 1995; Jacobsen and Höfel, 2003; Schupp et al., 2000).

The brain responses associated with liking vs. correctness ratings may also provide evidence for the hypothesis according to which affective judgment processes precede cognitive ones and require only primitive stimulus analysis, as suggested by Zajonc (1980; see also related findings by Peretz et al. (1998) on recognition of basic emotions in music). In our study, if the first brain events elicited by the ending chords are most prominent in association with the liking judgment task, then the Zajonc (1980)'s hypothesis would be confirmed. In the opposite case, if the incorrectness of the final chords is neurally detected mainly at early latencies (e.g., at 150 ms as expected from the ERAN findings) and only subsequent potentials characterize the liking judgments, contrary hypotheses suggesting the primacy of cognitive processing on liking would be supported. A third alternative hypothesis derives from the most recent theories of aesthetic processing, which include several stages from initial emotional reactions, to cognitive processing, and finally late conscious appraisal (Jacobsen and Höfel,