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From Vivaldi to Beatles and back: predicting brain responses to music in real time

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ABSTRACT

Background

In a recent study we introduced a novel approach for investigating continuous music processing in the brain (Alluri et al., 2012). We used ecological musical material (an instrumental modern tango) in a naturalistic setting wherein participants listened to the stimulus uninterruptedly without distraction by any experimental task unlike previous imaging studies that used controlled settings. We found auditory, limbic, and somatomotor-related brain areas to be associated with musical feature processing. The generalizability of these results, however, is yet to be assessed. We here extend this novel approach to other musical stimuli.

Aims

We aimed at predicting brain activity in relation to acoustic features extracted from musical pieces belonging to various genres and including lyrics. We also assessed the robustness of the hence created models across stimuli via cross-validation. To assess the generalizability of the models we further extended the cross-validation procedure by using the data obtained in Alluri et al. (2012).

Method

Participants (N = 15) were measured with functional magnetic resonance imaging (fMRI) at Aarhus University Hospital while they listened to two sets of musical pieces, one comprising instrumental music representing compositions from various genres (jazz, classical, rock and blues) and the other a medley from the B-side of Abbey Road by the Beatles containing lyrics. The former stimulus set will be referred to as Medley and the later as Beatles hereon. The time-series of the brain signal were extracted voxel-wise per participant. We used an approach similar to Alluri et al. (2012) for investigating continuous musical feature processing in the brain. Acoustic features were extracted from both stimulus sets using the MIRToolbox (Lartillot and Toiviainen, 2007). Principal component analysis was performed on the acoustic features of each stimulus set. Following this principal component regression models were trained separately for each stimulus set by using acoustic feature time-series as independent variables and the fMRI time-series as dependent variables. Subsequently we performed cross-validations of the Medley and Beatles models wherein the brain responses elicited by the first stimulus were predicted using the regression model of brain responses to the second stimulus and vice versa. Correlation was performed between the predicted and the original brain responses. Significance of the observed correlations was estimated by employing a Monte Carlo simulation approach. A significance level of $p < .001$ was used to threshold the correlation maps. The thresholded maps were then subjected to cluster correction in order to decrease Type I errors. Following this, in order to obtain the areas common to both the cluster-corrected maps, an intersection operation was performed. The result then displays the regions in the brain, which can be significantly predicted by the pair of the respective models. Subsequently, such pair-wise comparisons were also performed between the tango Adios Nonino from Alluri et al. (2012) and the two stimulus sets.

Results

Results highlight the right-hemispheric superior temporal gyrus (STG) (BA 22) as the core structure for processing complex acoustic features within musical pieces from various genres. We found overlap between the cross-validation results of the Medley and Beatles in the right-hemispheric structures, including the superior temporal gyrus and the insula.

The common areas as a result of comparing the Beatles and Piazzolla models comprise the right STG (BA 22), Heschl's gyrus (BA 47) and the Rolandic operculum. Models based on the Medley and the Piazzolla were able to predict in addition to activation in bilateral auditory cortices (BA 22 and BA 47), activation in the right-hemispheric rolandic operculum, superior parietal gyrus (BA 7) and postcentral gyrus (BA 5).

Conclusions

Using this novel method of continuous fMRI recording, brain activity in response to musical feature processing in supratemporal auditory areas and somatomotor areas can be predicted with significant accuracy. Despite differences between the musical pieces with respect to genre and presence of lyrics, the cross-validation of brain activations indicate that auditory and associative areas indeed are recruited for the processing of musical features independently of the variation in the informational content of the music. The right-hemispheric dominance displayed in the results suggests that the presence of lyrics might confound the processing of musical features in the left hemisphere. Models based on purely instrumental music revealed that in addition to bilateral auditory areas, right-hemispheric somatomotor areas were recruited for musical feature processing. In sum, our novel approach reveals neural correlates of music feature processing during naturalistic listening across a large variety of musical contexts.

Keywords

fMRI time-series, acoustic features, regression, cross-validation, naturalistic music stimuli

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