Investigating Autonomic Brain Regions with Naturalistic Stimuli: An fMRI Study

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Introduction

The autonomic nervous system is under control of cortical and subcortical brain regions. Cerebral structures repeatedly found to be involved in autonomic and especially cardiac regulation include the insular cortex, anterior cingulate cortex (ACC) and medial prefrontal cortex (mPFC) as well as amygdala, hippocampus and thalamus. They are part of the central autonomic network (CAN) known to be important for the integration of autonomic output.

Many different approaches have been used to elicit autonomic response in experimental settings, including motor or cognitive tasks. Cardiac output, such as heart rate (HR) and heart rate variability (HRV), is widely used as an indicator of autonomic activity.

Objective

To investigate whether naturalistic stimuli constitute a suitable approach to study autonomic brain regions in healty subjects, we analyzed a preexistent fMRI dataset acquired during free movie viewing.

Materials and Methods

The dataset analyzed in this study was collected by Hanke et al. (2014) and Hanke et al. (2016).

Sample and Stimulus

Brain imaging and pleth pulse data from 14 healthy subjects were analyzed (6 females, mean age: 28.9 years, range: 21 - 39 years, SD = 5.24 years). The stimulus material used during fMRI acquisition consisted of a shortened audio-visual German-dubbed version of the movie Forrest Gump (R. Zemeckis, Paramount Pictures, 1994). The study was approved by the local ethics committee.

Data Acquisition

- T1-weighted structural images: 3-Tesla Philips Achieva; 3Dturbo field echo sequence; TR: 2.5 s, TE: 5.7 ms, voxel size: 0.7 x 0.7 x 0.7 mm^3; 274 saggital slices.
- T2*-weighted functional images: 3 Tesla Philips Achieva dStream; echo-planar imaging; gradient echo; TR: 2 s, TE: 30 ms, voxel size: 3.0 x 3.0 x 3.0 mm^3; 35 axial slices.
- Recording of cardiac trace with a Nonin 8600 FO pulse oxymeter (simultaneously to fMRI acquisition).

Data Analysis

FMRI data analysis was carried out using FSL (https://fsl.fmrib.ox.ac.uk/fsl/fslwiki/). Pre-processing included motion correction, non-brain removal, spatial smoothing (5 mm), and highpass temporal filtering.

A general linear model was then fitted to the fMRI data. Two regressors indexing cardiac function were created for GLM analysis: heart rate (HR) and the high frequency component of heart rate variability (HRV HF). Regressor values were based on the individuals' pulse trace. For HR, beats per minute (bpm) were calculated at each systolic peak for the time period until the next peak. For HRV HF, interbeat intervals (IBI) between each systolic peak and the subsequent one were calculated, followed by power spectral analysis using HRVanalysis (https://anslabtools.univ-st-etienne.fr). A positive and a negative contrast was defined for each regressor. One subject had to be excluded from third-level analysis since spectral analysis failed.

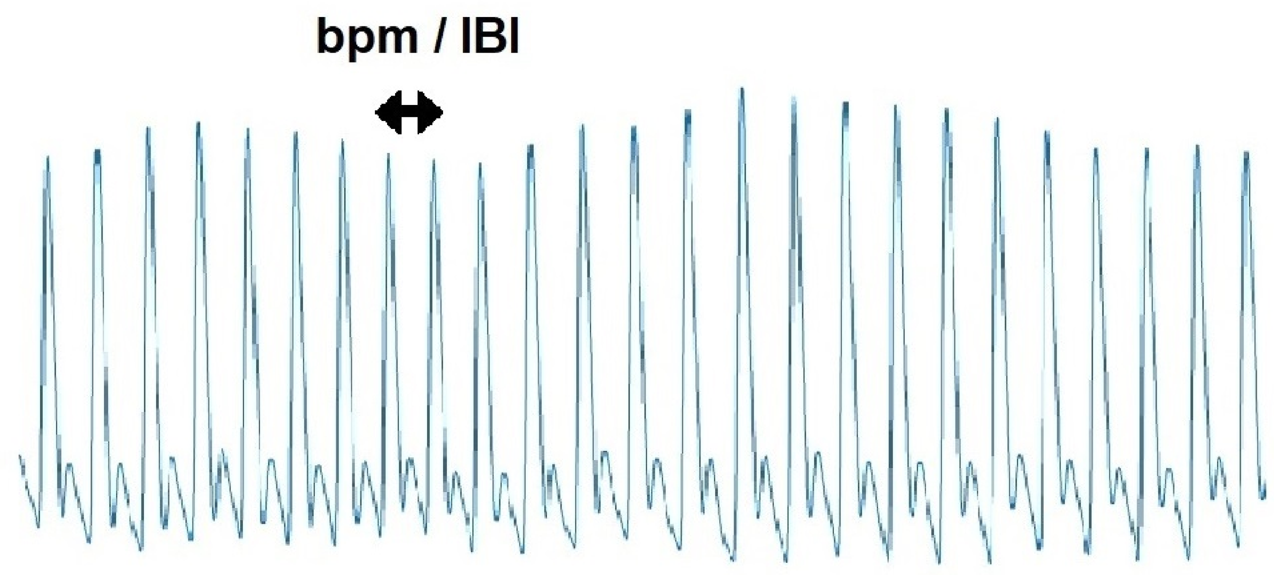

Figure 1: Pleth pulse time series. Beats per minute (bpm) and interbeat intervals (IBI) were calculated to create the two regressors HR and HRV HF.

Results

GLM analysis on the group level revealed a significant negative association between HR and activity in the left frontal and temporal pole, bilateral ACC and paracingulate cortices, amygdala, hippocampus, planum polare, orbitofrontal cortex, and fusiform cortex, as well as left posterior cingulate and precentral gyri ($Z \geq 3.1$, $p \leq 0.01$).

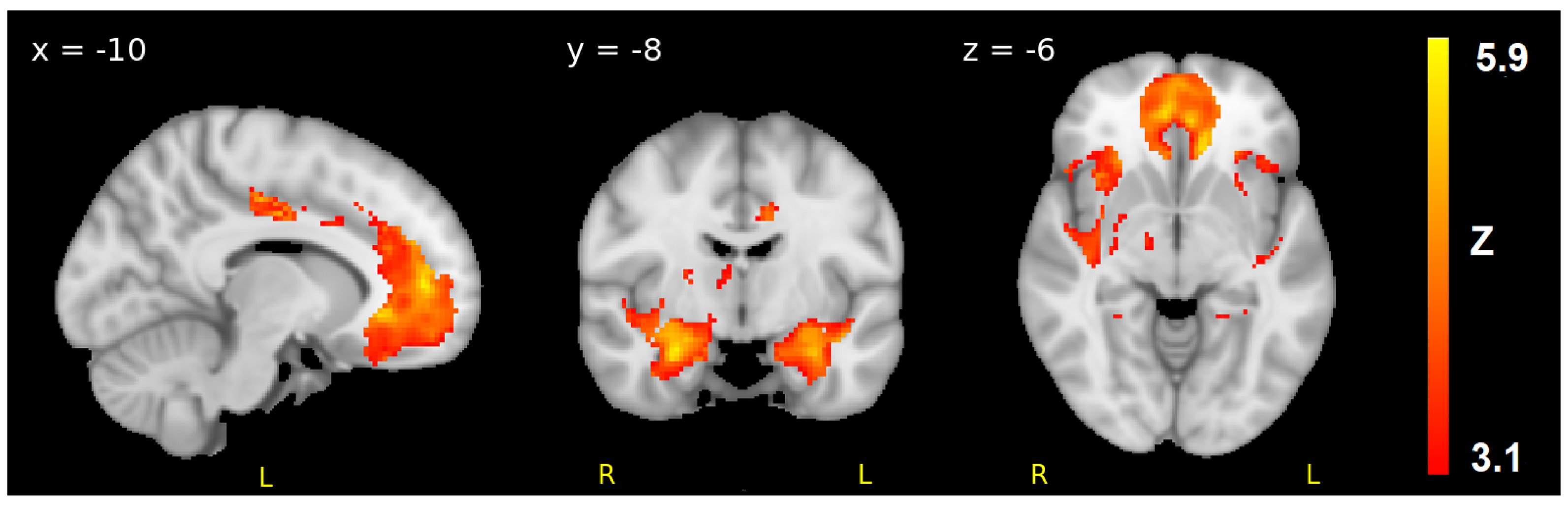

Figure 2: Brain activation negatively associated with heart rate. Corrected cluster significance threshold $Z \geq 3.1$, $p \leq 0.01$. CAN structures with significant bilateral cluster activation: ACC, amygdala, and hippocampus.

Conclusions

The aim of the present study was to investigate if movie paradigms constitute a suitable approach to examine autonomic brain activity as measured by fMRI. GLM results on the group level revealed significant brain activation negatively associated with HR, mostly supporting findings from earlier studies.

Our study contributes to autonomic research in terms of movie paradigm applicability during fMRI recording. It is self-evident that further undertakings are needed to support our findings. A successful implementation of naturalistic stimuli in autonomic research would not only improve ecological validity in comparison to standardized task-paradigms but also enhance practicability of experiments in patient groups or young subjects.

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