Resting in peace, noise or with instructions: the influence of scanner background noise on the default mode of brain functions

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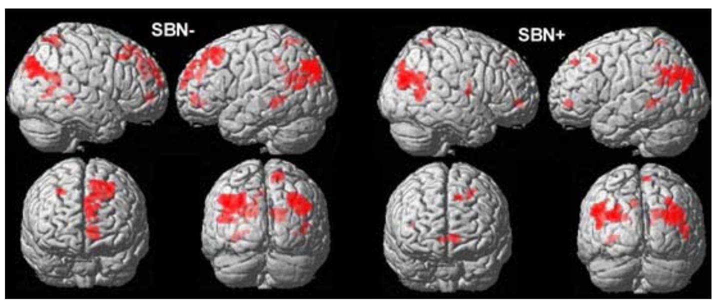
Introduction: Many studies have identified specific brain regions that are activated during rest and deactivated during attention-demanding goal-directed but not passive visual tasks, the so called 'default mode of brain functions" (DMBF, e.g. [1]). However, many of these studies have been conducted in the presence of scanner background noise (SBN). Assessing the DMBF or the "resting state" in the presence of a loud auditory stimulus (SBN) that has been shown to lead to increased activation in auditory regions might differ from the assessment of the DMBF during uncontaminated silence. Additionally, studies have suggested that brain function requires additional attentional resources in studies with continuous SBN compared to studies with less SBN. Furthermore, nonlinearity effects in response to SBN have been reported, suggesting that SBN in the experimental and control conditions is not "cancelling" out when contrasted against each other [2,3]. We hypothesized that the SBN has an influence on the default mode of brain functions by adding an attentional component to both the resting and active conditions and examined this hypothesis by varying the degree of scanner background noise in a verbal working memory task and a "silent" baseline (no stimulus presented). Furthermore, we were interested whether activation during the resting state (DMBF) can be altered by different attention modulating instructions during the resting periods.

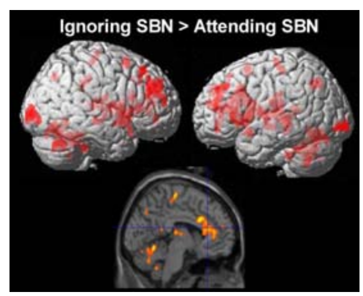
Methods Study 1: The fMRI scanning was conducted with a 3.0T GE Signa scanner (General Electric, Milwaukee, WI) using a custom-built volume head coil. BOLD measures were collected using a spiral in/out T2* pulse sequence [4] with 30 slices covering the entire brain (64x64 voxels, 3.43 mm inplane resolution, TE 30 ms, 4mm slice thickness with 0.5 mm slice skip). Two types of acquisitions were used, a conventional continuous acquisition that included SBN throughout (SBN+ condition), and a sparse sampling acquisition [STsamp; 1,2,5] that measured responses following periods of silence (SBN- condition). The imaging procedure (TR/FA/number of time frames, clustered vs. continuous acquisition) varied for the two experimental conditions, but slice prescription was kept constant as was the approximate duration of the scans. During the SBN- acquisition, the 30 slices were acquired in the first 1.995s of the 16s TR period, while for the continuous scan condition the 30 slices were spaced evenly throughout the 2s TR. Twelve subjects underwent two experimental runs (SBN- and SBN+). They listened to a series of four words and decided whether two of the words were identical. This was contrasted with a silent rest condition. Furthermore, we selected 64 evenly spaced images out of the 516 images in the SBN+ condition. The selected scans corresponded in time with the 64 images in SBN- and made it possible to directly compare the default mode of brain function for SBN+ and SBN-. This was done by convolving the silent periods (no stimulus) with a hemodynamic response function to test the contrast (silence > words).

Methods Study 2: The fMRI scanning was conducted on a 3.0T Tim Trio Siemens system (Siemens Medical Solutions, Erlangen, Germany), using a Matrix receive head coil and a whole-body transmit coil. BOLD measures were collected using a single-shot gradient echo sequence covering the entire brain (30 slices, TR=200ms, TE=30ms, FOV=200mm x 200mm, matrix 64 x 64, in-plane resolution 3.1mm x 3.1mm, 5mm slice thickness 5mm with 1mmslice skip). During a baseline phase, 20 subjects were instructed to relax and to focus on a fixation cross (A-neutral). Following that, subjects were instructed to change their attention towards the SBN depending on a visual cue, either carefully attend to SBN (A+) or ignore SBN (A-) The number of time frames was kept constant for the baseline phase and the two attention condition.



Results Study 1: Our analysis revealed a typical "default mode of brain function" network for SBN+ and SBN-. However, the deactivation was much more pronounced during the silent (SBN-) than for the conventional design (SBN+). Our results suggest that SBN suppresses components of the default mode of brain functions during resting periods. Our results further suggest that the suppression of DMBF components during resting periods with SBN may be explained by an increase in the cognitive load during the resting periods due to listening to SBN (sensory stimulation). Several studies have shown that the DMBF is diminished when a cognitive demanding task is being performed leading to a reduction in DMBF regions [e.g., 1]. Additionally, our results suggest that listening to SBN while performing an active verbal working memory task leads to increased deactivations in some regions of the DMBF due to the increased cognitive task load resulting from the inhibition of the SBN. Thus, SBN appears to diminish activation in DMBF regions during rest, and may enhance deactivation in DMBF during an active task.

Results Study 2: Our results show differences in activation between A-neutral, A- and A+. Ignoring the noise relative to the uninstructed baseline led to activation of medial, middle and inferior frontal gyrus. Ignoring the noise, relative to attending to it revealed increased activation in various brain regions that have been frequently reported to be part of the DMBF, including medial frontal regions and anterior cingulate. Attending to SBN compared to ignoring SBN resulted in increased activation of bilateral primary and secondary auditory cortices.



Discussion: Our results suggest that the default mode differs when assessed in the presence of SBN compared to the absence of SBN and therefore seems also to be influenced by passive auditory stimulation. Listening to words and silence during SBN (SBN+) might lead to increased attentional demands in comparison to listening to words and silence without SBN (SBN-). Furthermore, the results of study 2 suggest that attention modulating instruction changes can lead to alterations of the resting state activation. More importantly, these effects might differ between experimental and control conditions and may also vary between healthy adults and patients or children. Further studies have to clarify whether the use of a sparse temporal sampling technique might enhance the diagnostic value that has been proposed for the "default mode of brain function". Additionally, clear instructions on 'how to rest' seem to be crucial in studies that compare healthy fMRI-experienced controls and impaired subjects, children or naïve subjects

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