P-09

Properties of Artifacts in Functional MRI: Influence of Physiological Fluctuations

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INTRODUCTION

Physiological fluctuations of global head motion, respiration and pulsation are major sources of artifacts in functional MRI (fMRI). Reduction of artifacts is essential to improve sensitivity in detecting activated areas for brain functions. Among countermeasures against artifacts due to physiological fluctuation, correction of global head motion is usually used with rejection of pixels suffering from large fluctuation of signal changes. Influences of respiration and pulsation on motion correction have not been assessed yet. To know these influence, we analyzed artifacts in fMRI with and without motion correction (SPM96) by quantitative determination of artifacts based on thermal noise intensity[1]. Thus, properties of physiological artifacts were also revealed.

METHOD

Five male volunteers aged 22 to 26 years repeated 12-sec opposition movements of the left thumb and each of the other four left fingers (finger tapping) as a 24-sec periodical task (on/off = 12 sec/12 sec) during time series of imaging totally 192 sec. Experiments were performed on a 1.5 T standard clinical scanner (Siemens MAGNETOM Vision) using a head coil. A single shot EPI pulse sequence was used with the condition of TR/TE = 3000/60 msec, flip angle = 90°, slice thickness 5 mm, slice gap 1.5mm, NEX=1, FOV 270mm, matrix size 256×192, 5 axial slices. Sixty-five time-series images of the slice including motor cortex of fingers were obtained for each subject. The first 5 scans were discarded to remove transients produced as the system settled to dynamic equilibrium. We carried out 2D-motion correction to correct in-plane translation and rotation movements using SPM96[2]. The data sets of images with and without motion correction were analyzed to obtain power spectral intensity (PSI) images which were derived by Fourier transform of the time course of signal intensity in each pixel. The PSIs at the spectral frequency of the task paradigm (24 sec) were separated into 12 phase-divided images every 30° [3]. The phases correlate with the delay-time differences of signal changes of the frequency. To quantify artifacts and activated areas independently through subjects, pixels, which have larger PSI than a tested value determined by the spectral intensity of thermal noise[3], were depicted for those spectral images. Then the tested PSI and the tested phase-separated PSI images elucidated characteristic pattern of artifacts. The time intensity changes of the depicted pixels were also used to understand the property of fluctuation causing artifacts.

RESULTS

The motion correction was effective for all subjects as shown in the second and third column in Table 1. Phase-separated analysis differentiated the characteristics

of signal intensity changes in depicted pixels. In subject 1 who showed clear activated area, two different patterns of time-series of signal intensity in pixels appeared as artifacts in the PSI image at the task-paradigm frequency (1/24 Hz) were obtained depending on the speed of changes after the onset of the task (Fig. 1). The first pattern, which is of signal changes in the activated motor area, showed gradual changes taking about 9 sec. The second pattern showed faster changes. The pixels of this second pattern were located in the rim of the brain and disappeared after the motion correction, indicating task-related global head motion.

Table 1. Number of tested pixels in the PSI (power spectral intensity) and phase-separated PSI images at the paradigm frequency (1/24 Hz) with and without motion correctin (SPM). The phase (ϕ =60°) corresponds to delay of hemodymanic response.

Subject	Number of tested pixels			
	PSI image		Phase-separated PSI image (ϕ =60°)	
	w/o SPM	with SPM	w/oSPM	with SPM
1	150	53	14	21
2	189	114[1)]	69	35
3	49	55	10	2
4	29	15	1	1
5	298	49	81[2)]	9

1)influence of pulsation, 2) influence of respiration

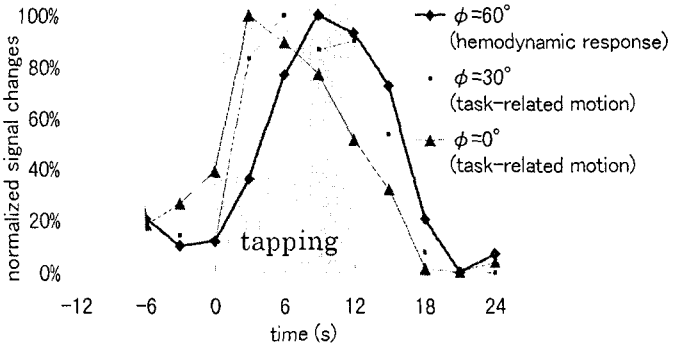
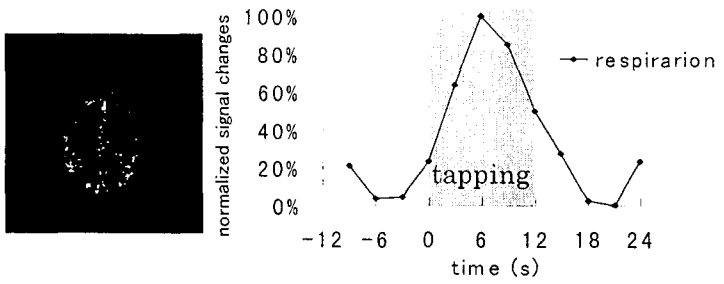


Figure 1. Normalized time intensity curves of signal change in areas of activation and task-related motion in subject 1, averaged 6 times in accordance with the task paradigm. The activated area was determined by the phase-separated image (ϕ = 60°). Artifacts due to task-related motion, which disappeared after motion correction (SPM), were the pixels depicted for ϕ =180° , 210° . Since the changes of the task-related motion were negative changes with the task performance, the changes were altered in reverse to appear upward with the task performance on the graph. The task-related motion shows faster changes than hemodynamic response.

The fourth and fifth columns in Table 1 show the extracted pixels corresponding to the phase (timing) of hemodynamic response. A large pixel number in the fourth column of subject 5 reflected the influence of respiration because the tested PSI image in Fig. 2 (A) is similar to the respiration-type artifacts, which were observed by other wide-spectral[3] range experiments using short TR[1]. The cumulated time-intensity curve of these pixels showing respiration-type artifacts in subject 5 is somewhat symmetrical (Fig. 2 (B)). Since these changes were reduced with motion correction as shown in Table 1, the major influence of respiration is understood to be global head motion associated with

breathing.

The third column in Table 1 indicates that the motion correction reduced the number of tested pixels to a level of a few tens except for subject 2. This subject suffered from the influence of pulsation that appeared especially in and around the superior and inferior sagittal sinus [1], as shown on the tested phase-separated (ϕ =60°) PSI image after the motion correction (Fig. 3). The time-intensity curve cumulated in these areas showed large fluctuation (Fig. 4). On the other hand, the tested phase-separated (ϕ =60°) PSI image before motion correction showed most of activation areas of bi-laterally activated motor area and supplementary motor area (Fig. 3). In fact, the time intensity changes of these areas were hemodynamic type (Fig. 4).



(A) (B)

Figure 2. (A) Tested PSI image at the task paradigm frequency for subject 5 without motion correction. (B) Normalized time intensity curve for pixels indicating respiration influence was averaged for 7 times in accordance with the task paradigm.

DISCUSSION

Our experiments show that artifacts are analyzed with respect to physiological fluctuations of global head motion, respiration and pulsation. Evidence that inflection point of time-intensity changes in activation area was 4 s after the start of the task (Fig. 1) is coincident with the report of hemodynamic changes[4]. While the task-related motion occurs conspicuously faster changes than hemodynamic response. The task-related motion artifacts are corrected by the motion correction of SPM.

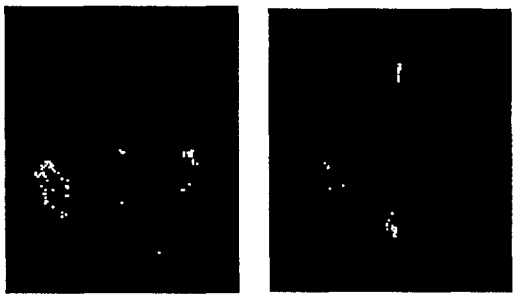


Figure 3. Influence of pulsation on motion correction (SPM). Phase-separated power spectrum images corresponding to hemodynamic time delay (ϕ =60°) with and without motion correction in subject 2 .

Although it was reported that susceptibility changes due to chest motion caused by respiration make artifacts in fMRI at a higher Tesla research system[5], we observed at 1.5 T that major influence of respiration was global head motion associated with respiration. Artifacts due to respiration were ascertained by the previously reported properties of pattern artifacts[1] and its symmetrical time intensity changes[5].

We observed the evidence that pulsation made motion correction deteriorate (Fig. 3). Pixels, which have large signal fluctuation, can usually be rejected by using

statistical processing like z-score. However, this kind of rejection may cause false negative artifacts in fMRI, as we observed in subject 2. The signal changes due to pulsation are aliased onto the spectrum of fMRI studies determined with a few seconds of TR. Since pulsation individually differs, its aliased spectrum occasionally influences at the task-paradigm frequency depending on the bandwidth of pulsation. The bandwidth was once observed to be about 0.06Hz by other wide-range spectral experiments using TR=0.25s[1]. Thus, the influenced spectral range by pulsation is about 30% of the spectral range (0.17Hz) of fMRI in this study. This may explain that only 1 subject out of 5 suffered from pulsation in the present experiment. Countermeasure against pulsation is most important for further reduction of artifacts in fMRI.

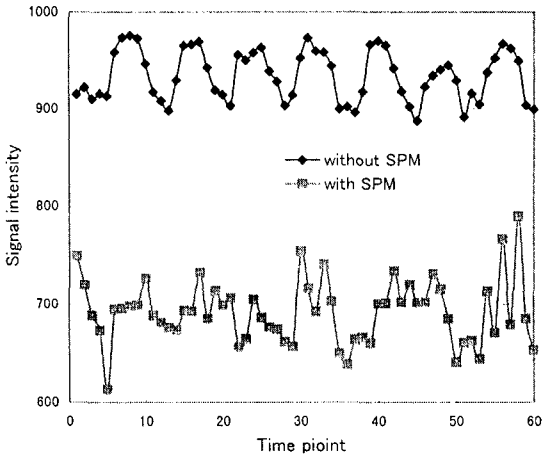


Figure 4. Time-intensity curves of pixels depicted by phase-separated power spectrum images corresponding to hemodynamic timing (ϕ =60°) in subject 2 with and without motion correction (SPM), respectively. While the changes without motion correction represent typical hemodynamic changes, the changes with motion correction show influence of pulsation.

CONCLUSION

The efficacy of motion correction was numerically evaluated. Results from this study demonstrate that both the task-related motion and the major influence of respiration are global head motion, which can be corrected, having their own properties of time-intensity changes. True reduction of the influence of pulsation is essential for artifact-free fMRI.

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