IN THE FOCUS

The Respiration Belt MR: a new device for parallel respiratory measurements
by Nicola Soldati

The investigation of physiological signals continues to receive a great amount of attention. The obvious reason is that such signals are deeply rooted in the nature of the subject of investigation (i.e. living beings) and they strongly interact with the organisms at various levels, from pure physiology to higher level cognitive functions.

Depending on the type of research, these signals can be useful when addressing specific questions, or they maybe simply add noise to the signals of interest. The latter is often the case in neuroscience, where strong physiological phenomena such as cardiac and respiratory cycles affect the measurements acquired by different techniques (EEG, fMRI).

Respiration plays a critical role in the MR environment, where it may not only be a confounding factor, but also a source of related artifacts. It can be linked to movement artifacts (due to the mechanical action of breathing - the typical respiratory rate of a healthy adult is 12-20 breaths per minute), physiological alterations (change of BOLD signal properties), induced field inhomogeneity (change of air volume in the lungs can affect the magnetic field locally), or interference with the experimental paradigm.

Studies using fMRI show that respiratory effects cannot be ignored, given that respiration induces great changes in terms of artifacts, and different respiratory patterns cause different oxygenation and finally change the fMRI measured BOLD signal (Thomason et al. 2005).

For this reason, advanced signal processing techniques have been developed with the goal of eliminating these confounding factors. One proposal was the use of Independent Component Analysis (ICA) to correct and remove structured noise (Thomas et al. 2002). However, recent work has shown that ICA alone cannot completely remove physiological noise from fMRI data (Beall et al. 2010) and moreover that higher order fluctuations in respiratory patterns induce detectable signal changes which can act as a confounding factor in research related to resting state (Birn et al., 2008).

Even if advances in data analysis techniques can provide better results at the cost of greater complexity, these results are considerably improved by parallel dedicated measurements of the sources of the artifacts. An efficient method which exploits parallel measurements for artifact correction uses acquired respiratory signals to create a principal regressor, along with other derived regressors obtained with a higher order analysis of the signal itself. This approach is known as RETROICOR (Glover et al., 2000). It is clear that a higher quality and sensitivity of acquired respiratory data will lead to an improved quality of all the regressors and finally to a higher quality of artifact correction and final denoised data, independent of the strategy adopted to correct for respiratory artifacts. With the aim of obtaining the best data quality and the optimal method of artifact correction we have developed the Respiration Belt MR, a novel device for the acquisition of respiratory signals within MR environments (Fig.1).

Working in an MR environment imposes several constraints ranging from the safety and care of the subject to the quality of the acquired data. Our solution offers advantages for all these factors. We decided to realize a respiratory belt, because this is a non-intrusive sensor which is comfortable for the test subjects (Cook et al., 2007).

The compatibility and safety of the Respiration Belt MR result from its technical characteristics.

One of its main features is that it is based on a pneumatic technology, unlike most solutions on the market. This avoids safety issues related to the introduction of electrical devices in strong magnetic fields. In addition, being pneumatic-based,

Figure 1

Respiration Belt MR Transducer

Figure 2

Deep

Shallow
the Respiration Belt MR is not a source of artifacts for the MR imaging, thus preserving the highest data quality and ensuring that no noise is induced on the MR recorded signal. Extensive tests have been carried out with scanners from various manufacturers with very satisfactory results.

Moreover, we developed our Respiration Belt MR with the aim of having a device with great sensitivity which is able to adequately follow different types of respiratory acts in a robust way. Figure 2 shows a slow and deep respiration (black line) and a faster and shallow respiration (red line) as measured by the Respiration Belt MR: The Respiration Belt MR is able to follow the dynamic of respiratory act over quite a wide range, showing a good sensitivity of the system. This makes of it a powerful and sophisticated tool to obtain high quality respiratory signals, and thus regressors for artifact correction, and also to investigate interrelation between physiology and brain organization more accurately. The higher sensitivity of the belt to respiratory dynamics makes it easier and more effective to compute higher order regressors describing fluctuations of respiration over time.

We are convinced that the new Respiration Belt MR represents a very useful instrument for advanced research over a wide range of applications and we will be pleased to welcome any of your further enquires.


