FMRI USING 3D PRESTO-CAN - A NOVEL METHOD BASED ON GOLDEN ANGLE HYBRID RADIAL-CARTESIAN SAMPLING OF K-SPACE

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INTRODUCTION:

PRESTO-CAN [1, 2] is an MRI reconstruction method that uses a hybrid sampling pattern see Fig.1, right. The angular increment between the profiles is close to the golden ratio [3]. The method was developed having fMRI-applications in mind and has shown to provide excellent temporal resolution and satisfactory image quality. However, this is the first time we have shown that it is possible to detect neural activity with fMRI using PRESTO-CAN.

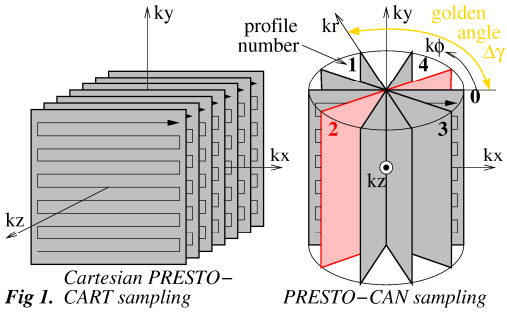

Fig. 1. *Cartesian PRESTO–CART sampling and PRESTO–CAN sampling*

MATERIALS AND METHODS:

3D sampling of k-space is normally performed using Cartesian sampling (PRESTO-CART) as in Fig. 1, left. PRESTO-CAN, on the other hand, uses a hybrid radial-Cartesian sampling as in Fig. 1 right, *i.e.* radial sampling in the (*kx,kz*)-plane and Cartesian sampling in the *ky*-direction. K-space is sampled using *N* radial ***profiles*** at *N* fixed angular positions, were *N* must be a ***prime number***. The angular increment between the profiles was close to the ***golden ratio***, *i.e.* $180°\cdot 2/(\sqrt{5}+1)\approx 111°$, but modified in order to guarantee fixed angular positions. When one ***dynamic*** (a full set of N profiles) has been acquired, it can be reconstructed using the gridding method. A block-design fMRI-paradigm is shown in Fig. 2. A volunteer alternates between two blocks each containing one task condition, in this case finger-tapping with either the left or the right hand. During the paradigm, profiles are acquired in k-space. In Fig. 1 there are *N*=5 profiles indicated and these are plotted with respect to time in Fig. 2. The profile numbers *n* = 0, 1, 2, 3, 4 agree with the time order t = 0, 1, 2, 3, 4, 0, 1, 2, 3,... ; where 0 is the onset time of a new block. A sliding window, overlapping a full set of profiles, moves forward in time. If the current profiles are 0, 1, 2, 3, 4, the time point of interest is chosen to be located at the central profile 2 (*i.e.* non-causality). The corresponding sample point of the paradigm is indicated with a red dot. If desired, for every new acquired profile, a new volume can be reconstructed to give a sample point of the paradigm. These sample points, not corresponding to profile 2, are indicated with black dots. By removing parts of the inner over-sampled k-space using a so called hourglass filter (indicated on the sliding window), the time resolution can be increased significantly.

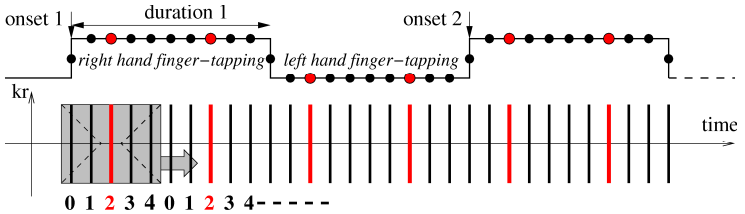

Fig. 2 *A block design paradigm with corresponding PRESTO-CAN profile acquisition.*

RESULTS:

The experiments were performed on a Philips 1.5 T Achieva MR-scanner. We used a PRESTO pulse sequence for the Cartesian-only (PRESTO-CART) sampling and a modified PRESTO sequence for the PRESTO-CAN sampling. The repetition time (TR) and echo time (TE) was TR/TE=24.8/40.3 ms and the EPI-factor was 15 for PRESTO-CART and the values were almost the same for PRESTO-CAN, namely TR/TE=25.5/41.1 ms and EPI-factor=15. The number of acquired profiles was 41 for PRESTO-CART and 79 for PRESTO-CAN. The time to acquire a full dynamic was 5 s for PRESTO-CART and 10 s for PRESTO-CAN, however a new volume was reconstructed every 3.3 s (Fig. 2). (For simplicity, the hourglass filter was not utilized in these experiments.) A volunteer was instructed to alternate 'finger tapping' with rest (right hand). The duration was approximately 20 s for both activity and resting periods. The total length of the sequence was 260 s for PRESTO-CART and 210 s for PRESTO-CAN. The software package SPM8 (http://www.fil.ion.ucl.ac.uk/spm/) was used for pre-processing and statistical analysis of time-series data. The reconstructed volumes were (80, 32, 80), but could equally well have been (80, 80, 80) for PRESTO-CAN. The reconstructed volumes were nearly identical; one z-slice is shown in Fig 3. The fMRI neural activation is shown in Fig 4 as an overlay on the volunteers own high resolution T1-volume. Consistent for both paradigms, the activation is located in the contra-lateral motor cortex of the tapping hand. The clusters shown in Fig 3 are significant at p<0.001 (uncorrected) but small clusters in the motor cortex survive p<0.05 controlled for the familywise error rate.

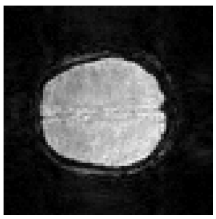

Fig. 3 *PRESTO-CAN reconstructed z-slice.*

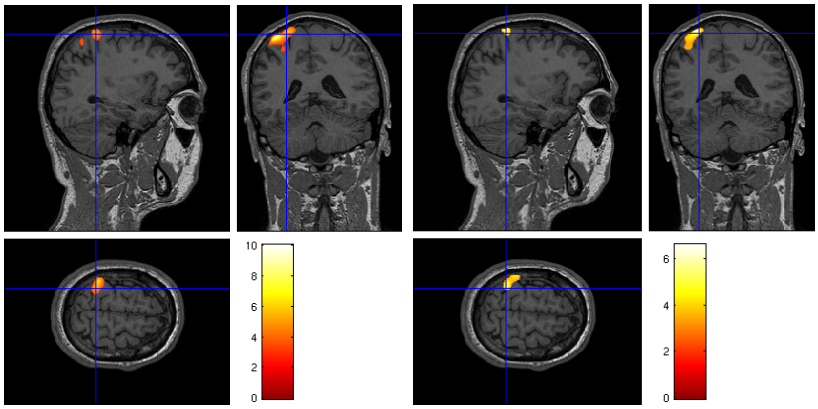

Fig. 4 *fMRI-activation in motor cortex. The MRI-data was based on PRESTO-CART (left) and PRESTO-CAN (right). Neurological orientation is used, i.e. left-to-right in coronal views.*

DISCUSSION AND CONCLUSION:

We have shown that it is possible to detect neural activity using fMRI and 3D PRESTO-CAN, a 3D+time MRI acquisition/reconstruction method based on golden angle hybrid radial-Cartesian sampling of k-space. A major advantage is that a wide range of aspects of the 3D PRESTO-CAN scheme can be extended. For example, by utilizing the hourglass filter, the temporal resolution will increase considerably, something that was not demonstrated here. Another example is parallel imaging (using SENSE) which has been implemented (but is not shown here). One major advantage of the PRESTO-CAN sequence investigated here for neurological research is that it allows for whole brain coverage using isotropic voxels, in combination with either/both high temporal and spatial resolution. It can also be combined with unique 3D motion correction schemes.

REFERENCES: [1] Magnusson et al.: 3D Magnetic Resonance Imaging of the Human Brain — Novel Radial Sampling, Filtering and Reconstruction, Proc. of the 12th IASTED Int. Conf. on Signal and Image Processing, Acta Press, 2010. Available at: http://www.actapress.com/ and http://liu.diva-portal.org **[2]** Magnusson et al.: A 3D-plus-time radial-Cartesian hybrid sampling of k-space with high temporal resolution and maintained image quality for MRI and fMRI, ISMRM 19th, 2011. **[3]** Winkelmann et. al.: An optimal radial profile order based on the golden ratio for time-resolved MRI, IEEE Trans. Med. Im., Vol.26, No.1, 2007.

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