

Image Acquisition Order and Input Order of BOLD-fMRI Data for Slice Time Correction in fMRI Data Processing Tools

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Introduction

Using BOLD-EPI, one can obtain a whole brain coverage within a TR of a few seconds, but not every slice is acquired at exactly the same time. During an fMRI data preprocessing step, one can correct for the small time shifts using an algorithm called "slice time correction".

In this work, we present a solution to check how MR scanners acquire functional multislice images, we apply this method to extract the correct acquisition order of slices acquired with a Siemens 3T MR scanner and we derive the input for slice time correction to three fMRI data processing tools.

Methods

All images were acquired on a 3T system (MAGNETOM Trio Tim, syngo vB13 software, Siemens AG, Erlangen, Germany) using a T2* weighted echo planar sequence sensitive to BOLD contrast (ep2d_bold) with TR = 20000 ms, TE = 30ms, four or five slices (thickness 3mm). Gap was set to 800% (24mm) in order to easily determine the z-position of the slices. Eight series of images were acquired, each time with varying Acquisition mode (*Ascending*, *Descending* or *Interleaved*) and Image numbering (*Feet to Head* or *Head to Feet*). For the interleaved acquisition mode, the sequence was run twice, using 4 and 5 slices.

After the acquisition of the first slice in the volume, the subject was asked to rotate his head to the left as far as possible (Fig. 1, lower part). Based on the resulting mosaic images with the first slice (in time) in "normal" axial position (Fig. 1, upper part), it was possible to determine the correct acquisition order of the slices and the correct input order for SPM5⁽¹⁾, FEAT v5.63 for FSL 3.3⁽²⁾ and BrainVoyager QX 1.9⁽³⁾.

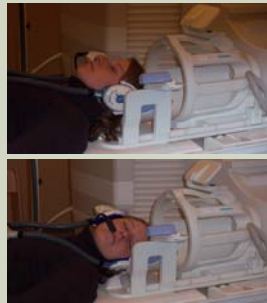


Fig. 1: head in "normal" axial position (upper) and rotated position (lower)

Results

Using EPI sequences, Siemens scanners always provide combined mosaic images. The measurement parameter Image numbering has an influence only on the spatial slice order in the mosaic; it did not change the temporal acquisition order. The chronological order in which the slices were acquired, can be derived as only the first slice is in normal axial position. For Siemens Magnetom Trio systems, the acquisition mode *Ascending* means that scanning will occur ascending in the z-direction, i.e. inferior to superior, while *Descending* is the opposite. Scanning *Interleaved* with a Siemens system is always interleaved-ascending. Using this acquisition mode, one should pay attention to the number of slices since the acquisition order differs for an odd or even number of slices: in both situations, the slice which was acquired last in time is always the last but one in the slice group.

Input in SPM is independent of the Image numbering parameter setting, but there is a difference for an odd or even number of slices in the *Interleaved* acquisition mode. The same goes for FEAT. For an odd number of slices, the "Interleaved" option can be used, while for an even number of slices a .txt file has to be created in which the user specifies the exact scan order (single slice number on each line; slice one is numbered "1", not "0"; see also left SPM-column in the table). BrainVoyager gives each slice in the mosaic image a number, based on the spatial appearance of these slices in the mosaic image and automatically takes this for a Feet to Head image numbering. However, if the image numbering was set to Head to Feet, BrainVoyager accepts that wrongly. Therefore, the user should change ascending to descending and vice versa in the BrainVoyager preprocessing user interface and neglect the checked box "Verified".

Table 1 shows the resulting images of the eight different runs. Correct slice order input for SPM, FEAT (part of FSL) and BrainVoyager is listed in table 2.

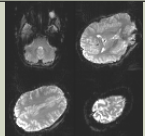
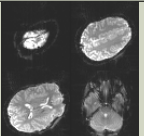
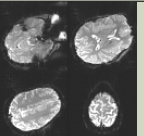
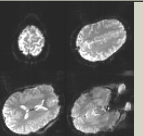
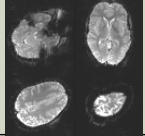
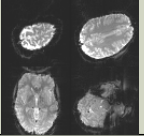
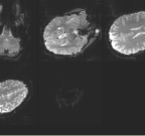
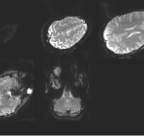
Run 1: Asc, F → H	Run 2: Asc, H → F	Run 3: Desc, F → H	Run 4: Desc, H → F
			
Run 5: Int, F → H	Run 6: Int, H → F	Run 7: Int, F → H	Run 8: Int, H → F
			

Table 1: resulting mosaic images for each of the eight possibilities

Run	Acquisition Mode	Image Numbering	Number of Slices	SPM	FEAT (FSL)	BrainVoyager
1	Asc	F → H	4 (even)	1 2 3 4 [1:1:n]	Regular up	Ascending
2	Asc	H → F	4 (even)	1 2 3 4 [1:1:n]	Regular up	Descending
3	Desc	F → H	4 (even)	4 3 2 1 [n:-1:1]	Regular down	Descending
4	Desc	H → F	4 (even)	4 3 2 1 [n:-1:1]	Regular down	Ascending
5	Int	F → H	4 (even)	2 4 1 3 [2:2:n 1:2:n-1]	Use slice order file	Ascending Interleaved 2
6	Int	H → F	4 (even)	2 4 1 3 [2:2:n 1:2:n-1]	Use slice order file	Descending Interleaved 2
7	Int	F → H	5 (odd)	1 3 5 2 4 [1:2:n 2:2:n-1]	Interleaved	Ascending Interleaved 1
8	Int	H → F	5 (odd)	1 3 5 2 4 [1:2:n 2:2:n-1]	Interleaved	Descending Interleaved 1

Table 2: correct input orders for three fMRI processing tools, for all settings

Discussion and Conclusion

All clinicians / researchers using fMRI data have to be aware of the parameter settings in the scan protocol, otherwise slice time correction may be applied incorrectly during data processing. For any MR system, slice acquisition order for functional imaging can easily be detected by scanning only a few slices separated by large gaps using a BOLD-EPI sequence.

For accurate slice order input in SPM and FEAT, the acquisition mode and the total number of slices (odd or even) are important. In BrainVoyager, the automatic slice time correction settings appear reversed when the image numbering was Head to Feet.

This work can be extended for other MR systems and other tools for processing functional images.

Acknowledgements

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References

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