Observer preference of magnetic resonance images at fixed imaging time

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Introduction

Anatomical magnetic resonance (MR) imaging is the preferred method for capturing soft tissue contrast. The user has considerable discretion over the appearance of the resulting images with regard to the field-of-view, resolution, orientation and isotropy of data. One of the main appreciable limitations in anatomical MR imaging is the inherently noisy data. Technological advances have improved coil geometry and number, gradient engineering and pulse sequence design. In spite of these efforts, imaging time is still a key limiting factor. Increasing imaging time offers improved quality of images either by increasing image resolution, signal-to-noise ratio (SNR), or both. No matter what the scan time, a choice needs to be made as to the tradeoff between resolution and SNR. To optimize anatomical MR imaging, viewer preference of the SNR/resolution tradeoff at fixed imaging time was investigated through a reader preference study.

Methods

High quality 3-dimensional images of 10 fixed mouse brains were acquired using a MR microscopy protocol[1]. Imaging was done on a 7-T magnet connected to a multichannel Varian*INOVA* console using the following scan parameters: fast spin-echo pulse sequence, TR/TE = 325/8 ms, 6 echoes (fourth echo at k-space center), TE_{eff} = 32 ms, 90° flip angle, 14 mm x 14 mm x 25 mm FOV, 432 x 432 x 780 scan matrix, 4 averages (NA), scan time 11.3 hours. Using parallel acquisitions and independent solenoid coils, three brains were imaged simultaneously. The protocol yielded T2-weighted images with 32-µm isotropic resolution. The mean SNR was 16 across the 10 brains, in homogeneous white matter.

Acquired data were degraded to simulate a *shorter*, constant acquisition time, but at the expense of SNR and resolution. Image resolution was manipulated by choosing a reduced k-space volume from the acquired data, and reduced signal averaging was effected by adding Gaussian white noise to k-space. Table 1 describes the tradeoff data simulated at two shorter imaging time-points (~2 and 5-h).

To determine reader preference a basic methodology was developed. Corresponding horizontal slices from tradeoff images *A-E* of a given brain were concurrently displayed in random order. Given control over window/level, zoom and pan, readers were requested to choose their first and second preference for each of the 10 sets of five tradeoff images in response to the question "Which image shows neuroanatomy best?" Image readers consisted of 14 imaging scientists acquainted with viewing medical images. First and second preferences were assigned weighted scores of 1 and 0.5. This basic experiment was then repeated four more times: (1) using coronal slices on a subsequent occasion 1-7 days later to test for reader consistency; (2) using three tradeoff images *F-H*, to evaluate the effect of image quality; (3) switching the task by changing the question to "In which image can you best distinguish subtle contrast differences between brain regions?", and; (4) switching the task to focus on fine detail by changing the question to "In which image can you best visualize fine structure and details in the brain?" Experiments (3) and (4) required only one choice (assigned a score of 1).

tradeoff	isotropic resolution (µm)	effective NA	mean SNR
2-h time-point tradeoff images			
A	32	1.0	6.4
B	40	1.6	11.3
C	51	2.5	20.2
D	64	4.0	35.9
E	81	6.3	63.0
5-h time-point tradeoff images			
F	32	1.0	10.0
G	40	1.6	18.3
H	51	2.5	32.9

Table 1 Resolutions and measured mean SNRs of simulated tradeoff images at 2 and 5 h fixed imaging times.

Results

Magnified regions of interest from the tradeoff images simulated for one brain, given an effective imaging time of 2 h, are shown in Fig. 1. The range of image quality seen is representative of all brains. Results of the original experiment (○) and the retest (□) are seen in Fig. 2 (error bars are SEM). Preference lies strongly for tradeoff *D* (mean SNR~36) in both test and retest with nearly identical scoring in each case. The intra-reader consistency, or the number of times a reader's first preference was the identical image in the retest experiment, was 56%, which is moderate. However, this value increases dramatically to 98% when determining the proportion of times a reader chose either their first or second choice, with order ignored, suggesting that readers were strongly committed to only two of the tradeoffs.

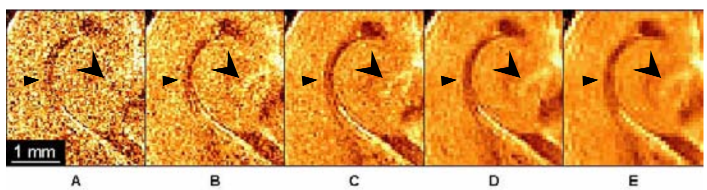

Figure 1 Example of tradeoff images *A-E* for one brain at the 2 h fixed imaging time. Shown is a magnification of the right fimbria (small arrowhead) and dentate gyrus (large arrowhead) from a horizontal slice.

Scores for the 5-h tradeoff images (experiment 2) indicated that tradeoff *H* was most favorable (SNR~33). Thus the preferred tradeoff for both time-points occurred at similar SNRs. Experiments 3 (diffuse contrast) and 4 (high contrast detail) showed a small shift of preference of approximately 20-30% towards higher and lower SNRs, respectively, implying that readers balanced these two objectives in the original experiment.

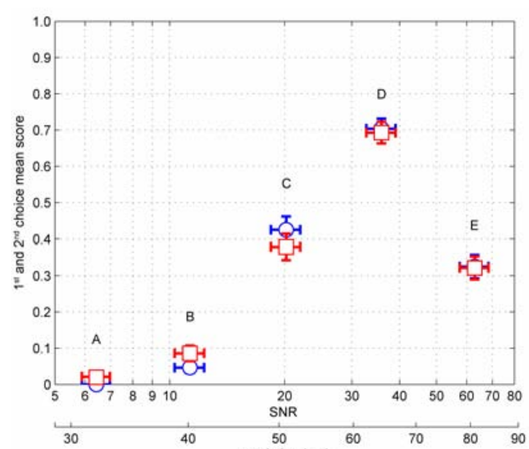

Figure 2 Mean scores based on first and second choices for tradeoff images in the test (○) and re-test (□) experiments.

Discussion

Previous work has looked at image preference for images at various SNRs and resolutions at varying scan times[2]. Alternatively, low contrast detectability as a function of resolution has been evaluated at fixed scan time[3]. The former work suggested that for T1W images, SNR in excess of 20 should be spent on improving resolution. That conclusion differs from the results found here.

Conclusions

For a fixed scan time in MR imaging, the reader preference for optimal viewing of anatomical images was found to be an SNR in the range of ~30-40. It is suggested that image resolution be chosen to produce this target voxel SNR. This finding is applicable to the clinical imaging community where maximal efficiency of available scan times is necessary given patient tolerance, wait times, and economic factors.

References

1 Henkelman RM, *et al*. High throughput microimaging of the mouse brain. Proc Intl Soc Mag Reson Med 2006; **14**; 2010.

2 Owen, RS and Wehrli, FW. Predictability of SNR and reader preference in clinical MR imaging. Magn Reson Imaging 1990; **8**; 737-745.

3 Constable, RT and Henkelman RM. Contrast, resolution, and detectability in MR imaging. J Comput Assist Tomo 1991; **15**; 297-303.