Effects of a High Static Magnetic Field on (Higher) Cognitive Functions

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Introduction

Since the early days of fMRI, it has been discussed whether the exposure to high static magnetic fields may have an effect on performance in cognitive tasks. Previous results are inconclusive, with most (1-3) but not all (4-6) studies reporting no significant differences related to field exposure. Studies conducted so far differ substantially in their experimental protocol, and only some of the manipulations used apply to typical fMRI investigations: (i) Only two studies tested the participants inside the bore of the magnet, in all other studies, participants were tested either sitting next to the magnet or outside the magnet room after exposure. (ii) Some studies instructed the participants to perform controlled head-movements to induce effects related to motion in a magnetic field (i.e. a time-varying field). (iii) Most often, standard neurobehavioral testing batteries were used to access possible alterations of cognitive effects, which are typically used in clinical settings but not in fMRI studies on cognition. It is also questionable if these tests are able to reveal more subtle differences in cognitive performance.

The aim of the current project was to test participants using a tightly controlled experimental protocol, which closely mimics the situation in typical fMRI investigations of cognitive processes. The sessions were performed within the exact same environment in the scanner, using the same stimulation and response devices. The order of sessions was balanced to control for training effects. Since it not known which cognitive processes might be affected, a variety of different, well-established paradigms was used.

Methods

Twenty-four fMRI-experienced participants performed six cognitive tasks, with the order of tasks being pseudo-randomized between participants. Following a training session in the reaction-time lab, familiarizing the participants with the tasks and establishing a baseline level of performance, two sessions inside a 3T whole-body magnet (Siemens MAGNETOM Trio) were conducted. Participants were positioned in the scanner in the exact same way as in standard fMRI investigations. They viewed stimuli via a mirror mounted on the head coil, looking onto a back-projected screen positioned at the rear end of the bore. Responses were recorded with MRI-compatible button-boxes. To balance out potential learning effects, half of the participants started with the magnet on field, the other half of participants started with the magnet being ramped down for a system upgrade. Participants were not informed on the condition of the magnet. The following well-established paradigms were used: n-back (working memory), Posner cueing task (spatial shift of attention), go/nogo (selective attention/response inhibition), Stroop (cognitive interference), task-switching (cognitive control), dual-task (divided attention/task coordination). Overall, one session lasted approximately 60 minutes.

Results

Participants could not tell whether the magnet was on or off upon asking. For each paradigm, the main effects of task for reaction-times (RT) and accuracies (AC) were compared between the two magnet sessions using paired-sample t-tests (exception: repeated-measures ANOVA for dual-task) (Figure 1). In addition, for every paradigm RT-means, RT-variances, and AC of single conditions were submitted into repeated-measures ANOVAs, using 'session' as a factor (Table 1) (exception: paired-sample t-test for go/nogo, see Figure 1 instead). Overall the performance was very similar in both sessions, and only one single test reached significance (n-back: interaction of session*condition for RT-variance), which is most likely an artifact.
To test whether the sample size used was too small to reveal subtle differences, we exemplarily calculated the required sample size under given alpha, power, and effect size (G*Power3; (7)) for task effect in the Posner cueing task: In order to reveal significant effects in RT under given conditions, a sample size of 314 would be needed (with a power of 0.8). It should also be noted that in order to make the test for potential difference as conservative as possible no correction for multiple comparisons was performed, i.e. all effects would be even smaller after correction.

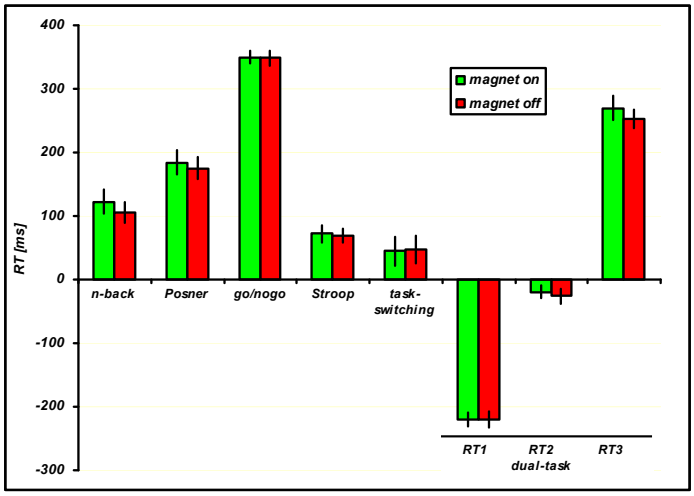

Figure 1: Task effects (RT): n-back (2-back vs.0-back), Posner (invalid vs. valid cueing), go/nogo (overall performance), Stroop (incongruent vs. neutral), task switching (switch vs. repetition), dual task (1st vs.2nd response over 3 intervals) (all p > 0.25 for RT, all p > 0.17 for AC, 2-tailed tests).

Task		*RT-mean*	*RT-variance*	*AC*
n-back				
	S	0.38	0.78	0.92
	S*C	0.20	0.02	0.24
Posner				
	S	0.98	0.86	0.75
	S*C	0.72	0.28	0.15
Stroop				
	S	0.94	0.73	0.41
	S*C	0.92	0.55	0.36
task-switching				
	S	0.24	0.63	0.87
	S*C	0.14	0.41	0.67
dual-task				
	S	0.39	0.09	0.67
	S*C	0.75	0.58	0.11

Table 1: Results (p-values) of repeated-measures ANOVAs for RT-means, RT-variances and AC, calculated for each paradigm (S = main effect of session, S*C = interaction of session and condition).

Conclusion

Using a carefully controlled experimental protocol closely mimicking standard fMRI investigations, effects of a 3T magnetic field on (higher) cognitive functions were investigated. We did not observe any significant influence of the magnetic field that would indicate safety concerns with respect to cognitive performance. Far larger sample sizes (i.e., hundreds of subjects) are needed in future investigation of potential subtle differences. Finally, comparisons of cognitive effects from testing situation inside and outside an MRI environment can be considered valid.

References

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