Investigation of recognition memory in fMRI using optimal stimulus arrangement with behavioral information from pilot studies

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Introduction

Behavioral and electrophysiological work has suggested that recognition memory is supported by separate processes: those that support the *recollection* of the details of previous experiences and those that allow us to recognize events based on *familiarity* without the recall of specific details [1]. Some researchers have hypothesized that recollection is specifically related to the hippocampus and parahippocampal cortex, whereas familiarity is related to perirhinal cortex [2]. Others have suggested that the hippocampus and MTL cortex work together in an undifferentiated manner to support both types of memory [3]. Initial tests of these ideas in humans have focused on patients with selective hippocampal damage, but have been impeded by inconsistent results that are likely complicated by the heterogeneity of amnesic patients and their lesion sites. In the present experiment we studied recognition memory by focusing on contrasts for recollection and familiarity. Recollection was defined as the recognition of the study orientation for common objects whereas familiarity was defined as recognition without the recollection of orientation.

Of particular interest in the design of tasks to study recognition memory is to find the best arrangement of stimuli to obtain a design that is optimal with respect to contrast detection power. Since for these type of experiments the design matrix is set up by sorting the fMRI trial responses *post-hoc* according to behavioral measurements, it is difficult to construct the best arrangement of stimuli. Predicting the optimal arrangement of events for maximum contrast detection power requires optimization that must include the behavioral probabilities of the anticipated responses. However, anticipated behavioral constraints have not been studied in the optimization of contrast detection power or design efficiency, and available software for design optimization cannot handle them. Several natural questions, which are the focus of the present research of recognition memory and optimal arrangement of stimuli, arise:

1. Can the order of the stimulus sequence be optimized for maximum detection power based on the probability of the behavioral outcomes from previous pilot studies?
2. Neglecting predictability of stimuli, is a block-type design the most efficient design for contrast detection?
3. How good is a random design for contrast detection? What are the tradeoffs between detection power and perceived randomness in this case?
4. How robust is an optimized design based on probabilistic behavioral information if the anticipated behavioral outcome is less accurate due to the fact that subjects' accuracy and timing may have improved?

To answer these questions, we designed a genetic algorithm that allows the incorporation of probabilistic behavioral information and optimized the design for maximum contrast detection power. Simulations were carried out for a recognition memory task in which responses are highly probabilistic, making this task an ideal test for the proposed genetic algorithm. Functional MRI data for a group of 18 subjects were obtained with the new algorithm and compared to findings in the literature.

Methods

Subjects were 18 students from the UC Boulder. FMRI was performed in a 3.0T GE HDx MRI scanner equipped with an 8-channel head coil and parallel imaging acquisition using EPI with imaging parameters: ASSET=2, ramp sampling, TR/TE=1.5sec/30ms, FA=70deg, FOV=22cm x 22cm, thickness/gap = 3.5mm/0.5mm, 30 slices, resolution 64x64, axial acquisitions. A standard 2D co-planar T1-weighted image and a standard 3D high resolution T1-weighted SPGR (1mm^3 resolution) were also collected. Subjects studied a long list of 268 pictures of common objects, half oriented to the right and half to the left. Functional scanning took place a day after the study session during memory testing with lists that contained pictures studied in the subjects' original orientation, pictures studied in the opposite orientation, and new pictures never studied. The length of presentation of each stimulus was three seconds. During scanning, 402 pictures (about 134 same orientation, 134 different orientation, and 134 new pictures) were presented. Subjects selected one of three memory judgments for each stimulus: studied picture with "same" orientation, studied picture with "different" orientation, or "new". The conditions were coded according to the stimulus (first letter) and the subject's response (second letter): ss (stimulus is "same", subject responds "same"), dd (stimulus is "different", subject responds "different"), sd (stimulus is "same", subject responds "different"), ds (stimulus is "different", subject responds "same"), nn (stimulus is "new", subject responds "new"). In the data modeling, we disregarded the other four possible responses (sn,dn,ns,nd) because these scenarios occurred only with very low probability. The recollection contrast is defined by $c_{\text{recollection}} = ½ ((\beta_{ss}+\beta_{dd}) - (\beta_{sd}+\beta_{ds}))$ and the familiarity contrast is $c_{\text{familiarity}} = ½ (\beta_{sd}+\beta_{ds}) - \beta_{nn}$, where β_{ab} are the estimated regression coefficients and the subscripts refer to the five conditions (ss, sd, ds, dd, nn).

Results and Discussion

Optimization of detection power for the proposed memory task under the experimental condition that stimuli are approximately balanced for 1., 2., and 3. order indicate an improvement of about 9% compared to a random design. The stimuli sequences obtained are pseudo-random (Fig.1). The genetic algorithm converged at generation 100 with 99 % of the maximum achieved (at generation 1000). Group activation maps using the optimized design for familiarity are shown in Fig.2 and for recollection in Fig.3 (unadjusted p-value = 0.001). All clusters with a cluster size of at least 424 mm^3 are significant at FWE < 0.05. The hot and cold color represents positive and negative contrasts, respectively. Images are in radiological convention (left is right and vice versa). Strong activations are present for recollection > 0 in the anterior medial prefrontal cortex, the lateral parietal cortex, the lateral temporal cortex, hippocampus, parahippocampal gyrus, and posterior cingulate cortex. For familiarity > 0, the strongest activations occur in the lateral anterior prefrontal cortex, the dorsolateral prefrontal cortex, the superior parietal cortex, the caudate nucleus, precentral gyrus, and peristriate (mid occipital) area. Most activations are bilateral with larger cluster sizes in the left hemisphere.

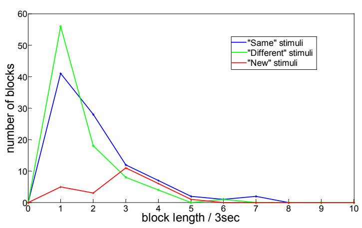

Fig1.

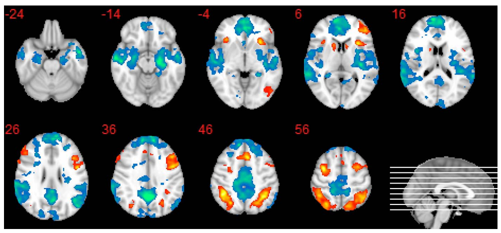

Fig.2

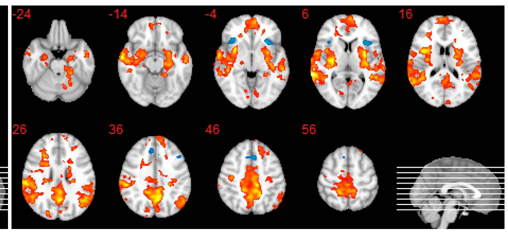

Fig.3

Conclusion

We proposed a genetic algorithm that includes probabilistic behavioral information to optimize the design of a recognition memory task for maximum contrast detection power. We investigated familiarity and recollection of common objects with different orientations. We have shown that the order of stimuli can be optimized for probabilistic behavioral responses, leading to better contrast detection power than a random design or the best block design. Furthermore, the optimized design is robust to small changes of the behavioral probabilities, which occur during actual fMRI scanning due to differences in the subjects' performance from the pilot data.

References

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