

FMRI MAPPING OF MOTOR - SERIAL DIGIT LEARNING TASK IN FRONTAL LOBE: METHODOLOGICAL DEVELOPMENTS

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Abstract-Serial digit learning test (SDLT) is traditionally related to mesial temporal lobes. As sequencing is closely related to the frontal lobes, SDLT is also thought to activate these areas. In this paper, methodology used in the functional magnetic resonance imaging (fMRI) of the hypothesised frontal activations is presented. By the use of a specially designed variant task we were able to detect such activations. The absence of such findings in the relevant literature may originate from the lack of proper techniques for these activations.

Keywords - Serial Digit Learning Test (SDLT), frontal lobe, cognition, functional magnetic resonance imaging (fMRI)

I. INTRODUCTION

Studies on clinical samples have shown that performance on Serial Digit Learning Test (SDLT) is dependent on mesial temporal lobe and hippocampus, both of which are responsible from learning and its consolidation [1,2]. However, an effective SDLT performance also requires such processes as utilisation of various cognitive strategies, temporal ordering of events and control of interfering effects [3]; all of these processes are among the functions of the frontal lobes [4,5,6]. In this paper we present the functional magnetic resonance imaging (fMRI) methodology that is developed to evaluate the relationship between SDLT performance and the frontal lobes [7].

II. METHODOLOGY

A. Scanner Hardware and Contrast Mechanism

1) *Hardware*: The study was performed on a 1.0-T system (Magnetom Expert, Siemens, Erlangen, Germany) equipped with gradient coils that can produce +/- 20 mT/m which allows echo-planar imaging (EPI) capability, and a standard quadrature head coil.

2) *Contrast Mechanism*: The fMRI contrast mechanism used is known as the blood oxygen level dependent (BOLD) contrast method. This method is based on the fact that the signal intensity changes due to the oxygenation of hemoglobin (Hb) in the blood vessels. Cortical neural activation causes increases in regional blood flow, resulting in increased capillaries and venous blood oxygenation. fMRI indirectly reveals neural activation by detecting this change of blood oxygenation. Activated brain areas can be visualized

using scanning techniques sensitive to the T2* changes such as echo-planar imaging and appear with bright signal intensities [8-10].

B. Psychometric Paradigm (Motor – SDLT)

All fMRI studies rest on a single fundamental assumption, namely that a signal is evidence of brain activation if it correlates with the activation protocol used. On the other hand, displacements caused by head movements may be responsible of almost all of the fMRI signal in extreme situations [11]. SDLT requires the oral interaction of the subject and therefore produces head movements that may exceed those tolerated by fMRI, preventing the collection of vital performance data. In order to overcome this problem, the “Motor - SDLT”, a variant task allowing measurements while obviating speech, was created [7]. During this task, subjects reported the digits on a touchpad using their dominant hand, hence eliminating artefacts.

C. Paradigm Presentation

In Motor - SDLT, the pace for the presentation and the retrieval of the digits was set to approximately 1 s for each of the digits. Subjects were carefully instructed to report each series in 12 s and rehearsed and monitored in the performance of the task before actual imaging has started using the third series of the SD-9 Form for SDLT (i.e. 8-5-2-9-4-1-7-3-6). Prior to examination all subjects were also administered the standard SDLT using the first series of the SD-9 Form (i.e. 6-1-3-5-2-8-7-4-9) to further familiarize them to the task and for statistical correlation.

The cognitive task used consisted of two phases: “Learning” phase with aural administration of the 9 digits of the second series (i.e. 3-9-7-4-8-5-2-6-1) of the SD-9 Form using MRI compatible and varying frequency earphones, and “recall” phase in which the subjects repeat the series with their dominant hand. The activation protocol during fMRI comprised of a baseline resting period (no activation) of 36 s, and 12 task periods (activation) of 24 s duration, each with 12 s of learning and 12 s recall phases (Fig.1). Onset and end of phases were indicated by “listen” and “repeat” commands administered through the earphones. The audibility of the commands was assured during a trial acquisition that was excluded from the analysis. Subject was advised to keep their eyes closed during the whole examination.

Report Documentation Page

Report Date 25 Oct 2001	Report Type N/A	Dates Covered (from... to) -
Title and Subtitle FMRI Mapping of Motor - Serial Digit Learning Task in Frontal Lobe: Methodological Developments		Contract Number
		Grant Number
		Program Element Number
Author(s)	Project Number	
	Task Number	
	Work Unit Number	
Performing Organization Name(s) and Address(es) Department of Radiology Trakya University Medical Faculty Edirne, Turkey		Performing Organization Report Number
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500		Sponsor/Monitor's Acronym(s)
		Sponsor/Monitor's Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited		
Supplementary Notes Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom.		
Abstract		
Subject Terms		
Report Classification unclassified	Classification of this page unclassified	
Classification of Abstract unclassified	Limitation of Abstract UU	
Number of Pages 3		

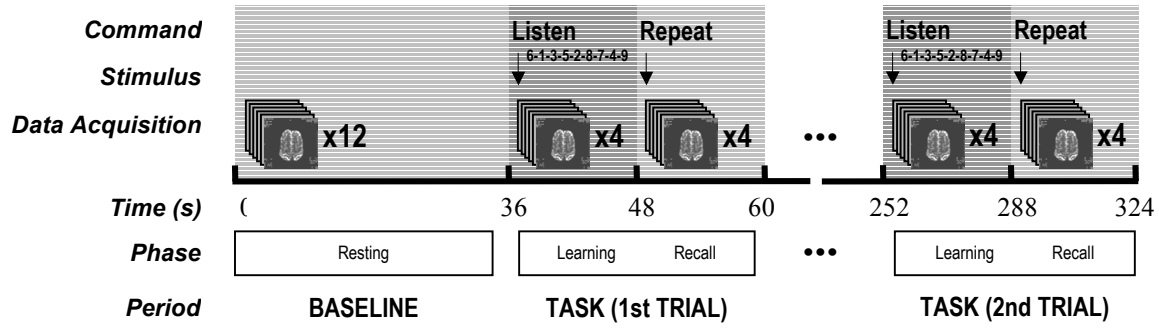


Fig 1. Schematic representation of Motor – Serial Digit Learning Task

D. Data Acquisition

A series of locator images was obtained from which anatomic reference images in the axial plane were acquired using sagittal and coronal images. The anatomical reference images consisted of ten contiguous T1-weighted (TR/TE/NEX=350/15/2) paraxial sections parallel to the bicommissural plane covering the frontal lobes from the ventral surface to high convexity. For the anatomical images the acquisition parameters are as follows: FOV 220x220 mm; Matrix: 128x128; Slice thickness: 6 mm, interslice gap: 3 mm. With the above mentioned technique every consecutive image represents a unique “level” of proportional grid in commissura anterior – commissura posterior (CA-CP) reference system, changing from level 2 to 11 (Fig.2) [12].

Functional imaging was performed in identical sections using free induction decay T2* single-shot gradient-echo echo-planar imaging (EPI) sequence (TR/TE/NEX=1.8/66/1). This 2D EPI sequence allowed ultra-fast measurements of susceptibility-weighted images. The scan time for every 10 contiguous functional sections was 2 s, and was repeated in every 3 s using identical acquisition parameters to anatomical reference images (i.e. FOV 220x220 mm; Matrix: 64x64, interpolated to 128x128; Slice thickness: 6 mm, interslice gap: 3 mm). A total of 108 functional series, each consisting of 10 slice (total 1080 images) were acquired during 324 s trial. Spatial resolution reached was calculated to be 3.44 x 3.44 mm.

E. Data Analysis

The resulting series of images are analyzed to extract signal changes that correlated with the task paradigms. According to the standard instructions on SDLT presentation, the data collected until two consecutive successful trials are taken into analysis. Z-score is used to calculate the difference image from the mean activation and no-activation images. In the analysis, the first 6 seconds (two acquisition) in baseline period were discarded. In addition, first 6 s (first 2 sampling) of every

listening and recall phases were excluded from the analysis to account for event-related latencies and rise times.

Temporally correlated changes in signal intensity for “baseline – task (learning and recall)”, ‘baseline – listening’, ‘baseline – recall’ and ‘learning – recall’ combinations were displayed as color-coded pixels and superimposed onto corresponding anatomic MR images.

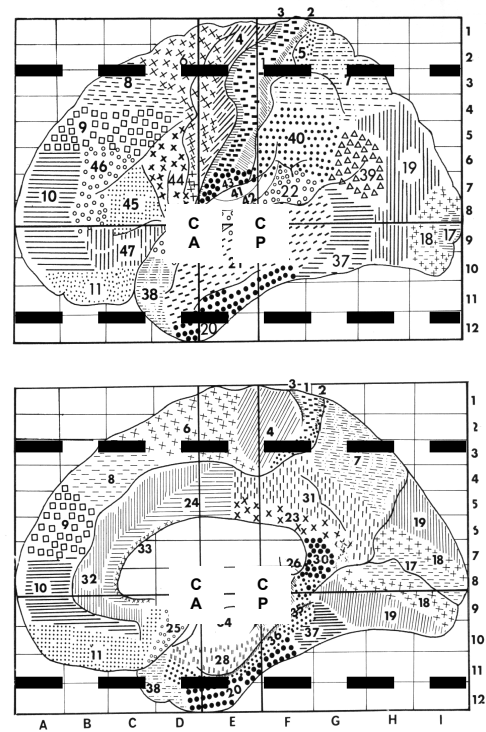


Fig. 2. The functional imaging volume on CA-CP system (Broken lines: Superior and inferior borders).

III. PRELIMINARY RESULTS

With the above mentioned technique, 17 normal volunteer with ages between 18 and 34 years were investigated.

The subject cooperativity to fMRI experiment was found to be excellent except for two subjects in whom the scanner noise and anxiety had resulted with unacceptable performance (i.e. faulty recall in all trials). In all subjects studied, task correlated activations were encountered in the frontal lobes, most prominent in the right frontal lobe [3,7].

Differential activation patterns were found between the learning and recall phases of the tasks (Fig 3).

IV. CONCLUSION

The study of mind is the attempt to put together findings and concepts from fields, approaches and techniques which are quite disparate but which are focused on the same phenomenon [10,13]. Currently, this attempt is condensed in neuropsychologic-neuroradiological integration. Although the underlying mechanisms of fMRI and problems are not fully known, the results obtained to date provide important impulses for future investigations of fMRI studies for the localization of SDLT and many other cognitive tasks.

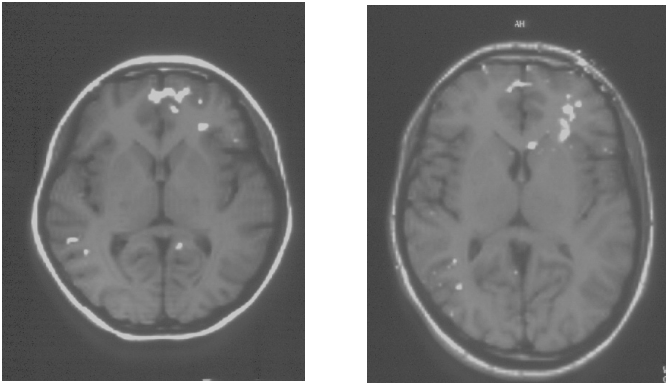


Fig. 3. Medial frontal activations during Motor – SDLT task in two different subjects. The imaging volume presented is the 6th level with respect to CA-CP reference frame.

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