

# A Picture Naming Task for Measuring Brain Activity with Functional MRI and Event-Related Potentials

M. E. Wagshul<sup>1</sup>, A. Azizian<sup>2</sup>, S. Fiore<sup>3</sup>, M. S. Korgaonkar<sup>4</sup>, C. J. Perkins<sup>3</sup>, T. Watson<sup>2</sup>, N. K. Squires<sup>2</sup>

<sup>1</sup>Radiology, Stony Brook University, Stony Brook, NY, United States, <sup>2</sup>Psychology, Stony Brook University, Stony Brook, NY, United States, <sup>3</sup>Neurology, Stony Brook University, Stony Brook, NY, United States, <sup>4</sup>Biomedical Engineering, Stony Brook University, Stony Brook, NY, United States

## Introduction

Aphasia is a language-related disorder resulting from acquired damage to the language networks of the brain, often a result of a stroke-induced infarct. While many aphasic stroke patients undergo spontaneous recovery, clinical trials have demonstrated that late recovery is possible, especially when intensive speech therapy is used in conjunction with pharmacotherapeutic agents. In order to understand the basis for this recovery, and thus to guide the development of new rehabilitation methods and drugs, it is critical to be able to study the functional changes which occur in the brain over the course of the therapy. Functional MRI (fMRI) has been used to study the nature of functional activation in the brain under various language-related stimuli, and to study changes in the brain during therapy [1]. This tool can provide a key component in our understanding of how the brain rewires itself in the wake of a stroke-induced insult.

At the same time, fMRI does not produce all of the key information about brain activation which may be needed. The BOLD technique, which serves as the standard for fMRI brain mapping, does not have the temporal resolution to distinguish between the rapid neural activation processes which occur as a result of a functional stimulus. For example, the early neural firing in the sensory cortex which is an obligatory response to sensory input is certainly different from the later firing which occurs during a semantic naming task. Event-related potentials (ERPs) [2], which utilize electrodes placed over the surface of the scalp to measure electrical activity, have the exact opposite spatio-temporal capabilities compared to fMRI. While an individual ERP electrode has the ability to record the temporal details of neural activity, the technology is not sophisticated enough to identify the precise location in the brain where that firing has occurred. Only crude localization, such as distinguishing between right and left hemisphere, is possible. The goal of this study was to design and test a language-related paradigm which could be used for both fMRI and ERP, so that the information from the two techniques could be combined to provide both detailed spatial and temporal information about functional activation in the brain during a simple language-related task.

## Methods

A simple picture naming task was designed which was expected to elicit functional activity information both in the fMRI and in the ERP settings. The task consisted of a series of line drawings that were easy or difficult to name, with the pictures presented in a random order. In the case of the ERP, picture presentation was completely random so that any given picture could be either a simple or a difficult image. Each image was presented until the subject pushed a button indicating that the name associated with that picture has been recognized and mentally "named". A total of 68 pictures was presented during the ERP session. In the case of fMRI, where a block design was required, picture presentation was less random: following presentation of a fixation cross for 17.5 sec, the subject was presented one series of 6 simple pictures, followed by a series of 6 difficult pictures. This pattern of events was then repeated three times, for a total imaging time of three minutes. In all cases, the subjects were not told the order of picture presentation in advance.

The categorization of pictures into "easy" and "difficult" groups was done on the basis of reaction times from a group of 10 healthy individuals, who were asked to view the pictures and push a button once the picture had been recognized and mentally "named". Based on the reaction times of the group, pictures were grouped into easy and difficult categories for subsequent fMRI and ERP tasks.

**fMRI technique:** The fMRI paradigm was run on a Philips Achieva 3T scanner. Imaging parameters were: TE/TR = 30/2500, FOV = 20 cm, matrix = 96 x 96, ST = 3 mm, voxel size = 2.1 x 2.1 x 3 mm, SENSE factor 2, 70 frames, total acquisition time = 2:55. Four healthy volunteers underwent the fMRI procedure (three of whom also underwent the ERP session, between 3-5 days earlier. Two of the ERP subjects were unable to complete the fMRI exam). Group analysis was performed on the fMRI data for the four subjects and average t-maps were generated for difficult minus easy contrast at a significance level of  $p = 0.05$  and co-registered onto a standard anatomical reference brain.

**ERP technique:** ERPs were recorded using a 64-electrode cap. Continuous EEG was recorded throughout the experiment, while pictures were flashed on the screen. Participants were instructed to silently name the object, and to press a button when the mental naming was complete. Off-line the EEG was divided into epochs that began 100 msec before the onset of the stimulus and continued for 1000 msec. The EEG epoch were sorted and averaged according to whether the evoking stimulus was in the "easy" or "difficult" category. Five healthy volunteers underwent the ERP procedure. EEG voltage maps from all five volunteers, at any given delay time, were averaged in order to produce the final group ERP maps.

## Results

The reaction time tests enabled us to group the original set of 79 pictures into 4 main groups: reaction time less than 720 ms, reaction times between 720 and 810 ms, reaction times from 810 ms to 1 sec and reaction times greater than 1 sec. The pictures with reaction times over 1 sec were rejected as being too difficult, and the reaction times between 720 and 810 ms were judged as being ambiguous as to their categorization. Thus, we were left with a set of 37 easy pictures with reaction time < 720 ms and 35 difficult pictures with reaction times between 810 ms and 1 sec.

**ERP Results:** Activation on the ERP studies in the visual cortex showed identical response for the easy and difficult pictures, indicating good reproducibility between these two parts of the paradigm. To isolate the naming-difficulty effect, subtraction-waveforms were constructed by subtracting the average ERP to the "easy" stimuli from the ERP to the "difficult" stimuli. There were two major peaks in the difficult- minus-easy maps, a negative peak at 400 ms with an amplitude maximum lateralized to the anterior left side, followed by a positive peak at 850 ms that showed broad anterior bilateral activity.

**fMRI Results:** The group mean t-maps showed a clear pattern of left-lateralized activation in the inferior frontal gyrus (Broca's area). At this level of sensitivity ( $p < 0.05$ ), no activity was seen in Wernicke's area, and no bilateral activation was seen.

## Discussion

The ERP data suggest that difficult-to-name items produced two time periods in which brain activity was greater than for easy-to-name items. The earlier activity was localized to the left hemisphere and appeared to arise in temporal (or perhaps temporal/frontal) cortex. The fMRI findings, that the activation is mainly lateralized in the left inferior frontal gyrus, provide further support for this theory and allows the localization of the ERP N400 peaks. These results are consistent with activation of known left-hemisphere language areas. Its occurrence at 400 ms is consistent with the large literature on the N400 component evoked by words that are unexpected in the context in which they appear [3]. The later activity, a diffuse positivity over the frontal lobes, could arise in a number of brain areas and may reflect the further processing (e.g., memory update) required for processing of stimuli that are less familiar. The lack of bilateral activation on the fMRI maps may indicate that the ERP and fMRI paradigm are dissimilar enough as to not evoke the same neural activation potential. In future experiments we will test an fMRI paradigm with rapid changes between easy and difficult pictures, a design more in line with the ERP experimental design. Nonetheless, these preliminary experiments seem to indicate that, with careful design of the stimulation paradigm, good correlation can be established between functional MRI and event-related potential results.

## References

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