

Functional MRI Report

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Imaging Procedures:

The functional MRI protocol consisted of three passive stimulation runs and six active response runs. The passive paradigm was used to localize elementary functions of the language and the visual cortex, while the active paradigm was used to interrogate the capacity to follow commands and switch between tasks. Two of the passive stimulation runs consisted of auditory stimuli and the other two consisted of visual stimuli. The active response runs consisted of naming objects, imagining finger-thumb tapping and recalling home objects.

The auditory paradigm was designed to target primary auditory functions as well as language comprehension. The auditory stimuli consisted of the narratives pre-recorded by a family member. Three segments of the narratives, lasting 18 seconds, were selected for each auditory run. These segments were modified to create the three auditory conditions: i) forward condition: the segment was played as recorded; ii) muffled condition: the high frequency component of the sound was removed so the segment's meaning was removed but the prosody was preserved, and iii) reversed condition: the segment was played backwards so its meaning and prosody were removed. The resulting nine auditory segments per run were intercalated with periods of no stimulation (baseline). The muffled and reversed speech conditions were expected to target auditory functions only, while the forward speech condition was expected to target both auditory and language comprehension functions. A total of 120 images were acquired in each run during 6 minutes.

The visual paradigm was designed to target primary visual function as well as higher-level visual functions as face recognition and place recognition. Three conditions were presented in each run: i) flashing reversing checkerboard, ii) faces (intermixed black and white photographs of familiar and unfamiliar faces), and iii) landscapes (black and white photographs of nature scenes). As in the auditory paradigm, the resulting nine visual stimulation segments per run were intercalated with periods of no stimulation (baseline) with only a fixation point on the screen. Each stimulation and baseline segment lasted 18 seconds. The three visual conditions were expected to target primary visual cortex. In

addition, the face condition targeted the face area in the fusiform gyrus of the temporal lobe and the landscape condition targeted the parahippocampal place area in the hippocampal gyrus. A total of 86 images were acquired in the visual run. A total of 120 images were acquired in each run during 6 minutes.

The Boston Naming paradigm was designed to target higher-level language functions, specifically involvement of Broca's area in language production as well as involvement of Wernicke's area. Different objects from the standardized Boston Naming task were used on each run during 40 seconds, preceded and followed by a resting period of 40 seconds. A total of 48 images were acquired in each run during 2.5 minutes.

The finger-thumb tapping paradigm was designed to elicit motor command following, to specifically target the involvement of primary motor area. The subject is expected to move or imagine moving the fingers on the right hand during 40 seconds on each run. This task period is preceded and followed by a resting period of 40 seconds. A total of 48 images were acquired in each run during 2.5 minutes.

The home object recall paradigm was designed to elicit memory and navigation through a familiar environment. It was expected to specifically target the involvement of hippocampal areas as well as language areas. The subject was asked to name the objects he/she finds in the designated room during 40 seconds on each run. This task period was preceded and followed by a resting period of 40 seconds. A total of 48 images were acquired in each run during 2.5 minutes.

Analysis Techniques:

Twenty-one slices covered the entire brain during each MRI image. Gross head movement was present at several times during the scanning session yielding image artifacts in some volumes. The resulting distorted volumes were discarded. Two software applications were used to analyze the data: SPM2 and in-house FMRI software. These packages utilize different statistical and motion correction approaches. Therefore, SPM is best suited for repeated alternating epochs while FMRI is best suited for short single epoch designs. This report is accompanied with sets of images for each condition and analysis techniques. All imaging parameters are summarized on the plan sheets.

Results:

a) Passive Paradigms

Auditory Stimulation:

All language conditions, forward, reversed and muffled, present very robust activation with the forward showing and muffled the smallest greatest volumes of activation. Language specific activation is observed in clusters that extent bilaterally over the

transverse temporal gyrus, the middle and the superior temporal gyrus (slices -20 to +0). In addition, bilateral middle frontal gyrus (slices +20-25) and left middle frontal gyrus (slice +10) are also observed. These clusters include primary and secondary auditory regions as well as putative Wernicke's area located in the left superior temporal gyrus.

The forward and reversed conditions extend their activation to the superior and medial frontal gyrus (slices +30-35) although those activations are not as robust as the ones observed in auditory areas. Likewise, the forward condition elicited a less robust activation in the superior cingulate gyrus (slice +25).

The comparison of the forward speech to the reversed speech condition (Forward NAND Reversed) reveals several clusters unique to the forward speech. Most notable is the activation of the inferior frontal gyrus (slice -10) that is indicative of Broca's area engagement. A comparable cluster is observed during the naming task (see below). Other unique areas include bilateral activation on the lingual gyrus (slices -10 to +0), bilateral precuneus (slice +10), right inferior parietal cortex (slices 5), the right (slice +20) and left (slice +25) middle frontal gyrus, and left superior frontal gyrus (slice +45). These areas are associated to high-level language processing.

Impression:

These data show a very well preserved language system that encompass not only the lower level language areas in the primary and secondary auditory cortex, but also regions of the temporal lobe that are specific for language comprehension as well as regions of the frontal cortex that carry out executive functions necessary for a functioning language system.

Visual Stimulation:

The checkerboard condition activates the left primary visual cortex (slices -30 to -20). In addition, right middle frontal gyrus (slices 0 and +20) and bilateral superior frontal gyrus (slice +15) are active.

The face condition engages the left primary visual cortex (slices -30 to -20) to a greater extent than the previous condition. The activity extends to secondary association cortices in both hemispheres including middle and inferior occipital gyrus (slices -20 to -5) as well as the inferior temporal cortex (slice -35 to -30). Right precuneus (slices +30) is also engaged. Furthermore, the activation in the face fusiform area of the right inferior temporal gyrus (slice -35) observed only in this condition suggests specific high-level processing of faces.

The landscape condition shows robust activation of primary visual cortex (slices -30 to -20) similar to the face condition. However, there is not observed activation associated to the parahippocampal gyrus responsible for the processing of landscapes.

Impression:

Primary visual cortex was engaged during the three visual conditions, with a more robust activation during faces and landscapes suggesting a differential processing of these stimuli. Specificity for faces was also observed. The engagement of higher processing areas specific for faces together with the early visual areas observed in the three conditions suggests that the visual system is well preserved. The lack of specificity observed for the landscape condition in comparison to that observed to the face condition might reflect the higher salience of familiar stimuli compared to non-familiar stimuli used in the landscape condition.

b) Active Paradigms

Boston Naming:

Language-sensitive cortex is active during the naming task. Specifically, there is activity associated to putative Broca's area in the left inferior frontal gyrus (slices 9-10) as well as putative Wernicke's area in the left temporal gyrus (slice 11). Activation of the medial frontal cortex, although not very robust, is indicative of active participation in the task. Activity is very robust in the visual cortex (slices 5-6) as well as in higher visual areas including the lingual gyrus and inferior and middle occipital gyrus. These visual areas are involved in processing the items to be named.

Impression:

The production part of the language system that depends on Broca's area seems to be well-preserved. The pattern of activity observed is consistent with processing the visual stimuli and volitional performance of the naming task.

Finger-thumb tapping:

Although several clusters of robust activity were observed, the expected activation in the left motor strip associated with right hand imagined finger movement was not observed. Activity was most robust in the inferior (slice 6) and superior (slice 10) left temporal gyrus, and bilateral paracentral gyrus (slice 16). In addition, there is clear activation of the visual cortex (slices 5 to 7) during the task elicited by the presentation of the flashing checkerboard concurrent to the motor task.

Impression

Activity elicited by finger-thumb tapping was not observed suggesting that there was not volitional participation in the task.

Home Navigation:

Although the presence of activity on the right hippocampal gyrus (slice +6) and the inferior parietal cortex (slice 12) are suggestive of engagement in the navigational task, the presence of many non-specific clusters makes the interpretation difficult. Furthermore, the observed activity is less robust than in other conditions.

Impression:

The specific activation related to the navigation components of the task is weakened by the presence of non task-related activity.

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