



IMAGING ATTENTIONAL NETWORKS

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Abstract

Many pathologies including attention deficit disorder, schizophrenia and depression include a reduction in the efficiency of attention. In order to understand some of this common pathology it is important to know the brain areas involved in attention. Three common functions of attention are:

- **Alerting** – the ability to prepare for a sensory signal
- **Orienting** – turning attention toward a sensory signal
- **Conflict** – selecting one dimension in the presence of competing information

We ran subjects in an event related fMRI experiment to find brain areas active for the three functions of attention.

Introduction

We have devised a simple attention network test (ANT) that can be performed by adults, children, patients and even non-human animals (Fan et al, in press). The ANT (see **Figure 1**) takes about half an hour and provides three numbers that indicate the efficiency of the networks that perform the alert, orient and conflict resolution functions. Our previous work with this test has provided evidence on its reliability, its heritability and the independence of the numbers for the three different functions (see Poster 417.2).

This study is the first to provide evidence on the brain areas involved in carrying out the ANT as a whole, although previous studies have examined the areas involved in the components of the ANT and lead to the hypotheses below.

Hypotheses

- I. **ALERTING**: will activate the frontal and parietal areas of the right hemisphere and thalamic areas related to norepinephrine (Coull, et al 1996; Marrocco & Davidson, 1998)
- II. **ORIENTING**: will activate superior parietal area and temporal parietal junction particularly on the right side. (Corbetta et al, 2000)
- III. **CONFLICT**: will activate anterior cingulate and lateral frontal cortex (McDonald et al, 2000).

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Methods

Participants

Sixteen right-hand normal adults (mean age = 27.2 years, SD = 5.7, range: 18-36 years; 8 female, 8 male) participated this study. They were scanned in a 3T MRI scanner while they carried out the ANT.

Acquisition of functional MRI data

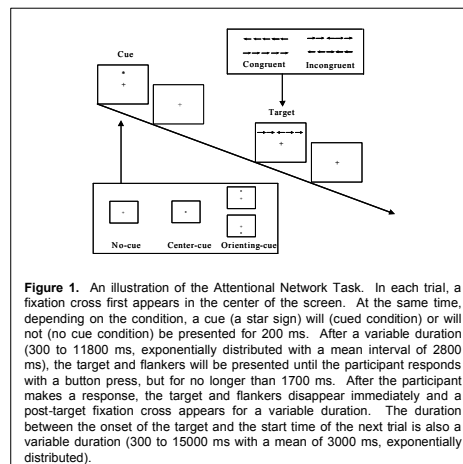
MR imaging was carried out using a 3T GE scanner. Functional scans were collected by using a T2* weighted EPI sequence (TE=35 ms, TR = 2000, flip angle=80) with an inplane resolution of 3.44 x 3.44 mm (64 x 64 matrix; 220 x 220 mm FOV). To cover the whole brain, twenty-four 5mm slices (skip 1 mm between slices) were acquired along the AC-PC plane.

Attentional Network Test (ANT)

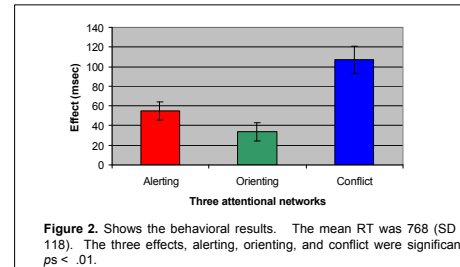
The details of ANT are illustrated in **Figure 1**. Stimuli consist of a row of 5 visually presented horizontal black lines, with arrowheads pointing leftward or rightward, against a gray background (see the three target conditions in **Figure 1**). The target is a leftward or rightward arrowhead at the center. This target is flanked on either side by two arrows in the same direction (congruent condition), or in the opposite direction (incongruent condition). The participants' task is to identify the direction of the centrally presented arrow by pressing one key for the left direction and a second key for the right direction.

We isolated brain activity associated with

- **ALERTING**: center cue – no cue
- **ORIENTING**: spatial cue – center cue
- **CONFLICT**: incongruent flankers – congruent flankers

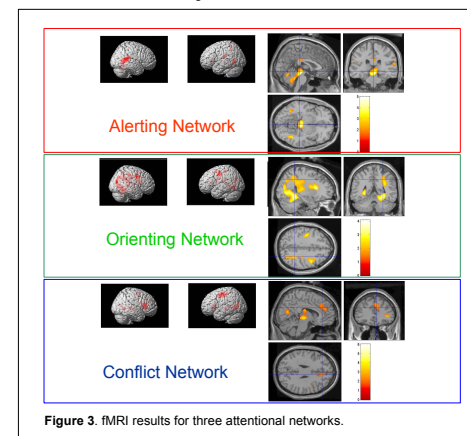


Results



fMRI results

- I. **ALERTING**: The classic fronto-parietal cortical activation along with the thalamus was found following the central cue as a warning signal. Area 7 activity was bilateral but inferior parietal and frontal activity was primarily on the left rather than as expected on the right side.
- II. **ORIENTING**: Activity was found in the left and right superior parietal lobe as expected. The temporal parietal junction (area 39) was not active in the group average, however, nearby activations in areas 37 and 41 may require more analysis of individual data.
- III. **CONFLICT**: Anterior cingulate plus right and left frontal areas were active as predicted, but several other areas were active as well reflecting the complex nature of the flanker task incongruent condition.



Discussion

The ANT provides three subtractions which we argue are related to alerting, orienting and conflict. Our current behavioral data was quite similar to what we had previously obtained from a larger number of subjects (40) run in a prior behavioral study (Fan et al, in press). In the larger study the three numbers appear to be largely independent in that there was no correlations across subjects and only minor statistical interactions.

The ANT fMRI data largely confirms the implication from behavioral data for three separate networks. A large number of areas were activated in each subtraction. Preliminary analysis suggests that the networks found active in each subtraction are rather distinct. One exception is area 7 which is activated both by alerting and orienting cues. However, as suggested in the introduction distinct transmitters are involved (Marrocco & Davidson, 1998; Davidson & Marrocco, 2001). Two other areas were found in common between the conflict and orienting networks, left area 6 and right area 37.

The activated networks fit somewhat with those hypothesized from the literature. One exception was that the alerting network involved somewhat more left rather than the predicted right hemisphere activation. We speculate that this arose because the alerting cue in this study was a single central asterisk and might have required a narrow focus of attention (left dominant) rather than the double cue used in previous behavioral work. Another exception was the lack of activation of the right temporal parietal junction for orienting. This may have been because we never used an invalid condition. The temporal parietal junction is maximally activated following invalidly cued targets (Corbetta et al., 2000).

Conclusion

Overall the fMRI ANT suggest that this single test does activate three mostly separate networks related to components of attention.

References

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