Neuroscience Letters 534 (2013) 177–181

Contents lists available at SciVerse ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

Attention network impairments in patients with focal frontal or parietal lesions

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HIGHLIGHTS

- Brain areas responsible for attention can be broken down into 3 networks.
- We examined patients with focal brain lesions using the ANT task.
- Patients with frontal lesions showed a deficit in the executive network.
- Patients with parietal lesions showed changes in the orienting network.
- Patients with temporal injuries showed no deficits in any of the 3 networks.

ARTICLE INFO

Article history:
Received 5 September 2012
Received in revised form
19 December 2012
Accepted 20 December 2012

Keywords:
Attention networks
Frontal lobe
Parietal lobe
Temporal lobe

ABSTRACT

Recently, research on attention has focused on 3 networks that are linked to separate brain regions, i.e. orienting, alerting, and executive control. The attention network test (ANT) is one of the methods to measure the three attention functions. However, neuropsychological investigations have not examined the anatomical disassociation of different attention networks with the same task. We compared the efficiencies of the 3 networks between brain-damaged patients (27 frontal lesions, 20 temporal lesions, and 21 parietal lesions) and healthy controls ($N = 58$) with ANT. Comparing the brain damaged group with the normal controls, a reduced efficiency of the executive network was found in patients with frontal lobe and parietal lobe injuries, and there was also a deficit in the orienting network in patients with parietal lobe injuries. Analysis of lateralization indicated the right hemisphere superiority to the alerting system. The present study found that the three attentional networks were selectively impaired following brain damage which affected different areas in the brain.

1. Introduction

Posner and Petersen [27] proposed that the brain areas responsible for attention were formed by a specific system of anatomical areas, which could be further broken down into 3 networks. These networks carry out functions of alerting, orienting, and executive control [19].

The attentional component of alerting involves the ability to maintain the alert state tonically and the phasic response to a warning signal [18]. The alerting system may relate with some frontal and parietal areas, particularly of the right hemisphere. These regions are activated by continuous alert signals [13]. The alerting system involves cortical projections of the norepinephrine system [17].

The orienting network involves the selection of information among numerous sensory inputs [19]. The research implies that the superior parietal lobe of humans is involved in orienting function of attention [1]. In some fMRI studies orienting task activates areas of the parietal and frontal lobes as well as the temporal–parietal junction, with a right hemisphere bias [10,12]. Substantial empirical evidence emphasizes a role for the parietal cortex in spatial cognition [31]. Evidence from lesion studies confirms the finding of multiple-space representations in the parietal cortex [23]. Blocking cholinergic input to the superior parietal lobe affects the ability to shift attention to cues [15].

Executive control of attention is most frequently measured by instructing a subject to respond to one aspect of a stimulus while ignoring a more dominant aspect [19]. Several studies have reported that executive function deficits are associated with frontal lobe damage, including frontal tumors [22], head injury [14], and frontotemporal dementia. The right inferior frontal gyrus (IFG) plays a role in inhibitory processes relevant for successful executive function, confirmed in the Stroop, Go/No Go, and other

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0304-3940/$ – see front matter
http://dx.doi.org/10.1016/j.neulet.2012.12.038

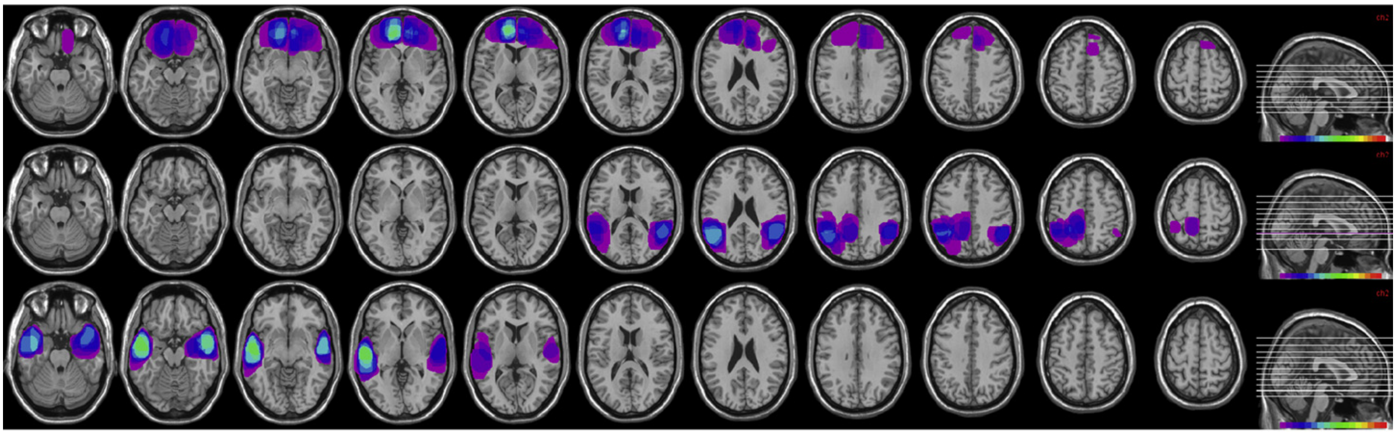

Fig. 1. Lesion location and overlap for patients with left- and right-sided brain injury: frontal lobe ($N = 27$), temporal lobe ($N = 20$), or parietal lobe ($N = 21$).

attention-demanding tasks [2,25,30]. Executive control of attention has been associated with the midline frontal areas (anterior cingulate cortex, ACC) and lateral prefrontal cortex [8], which are target areas of the ventral tegmental dopamine system [26]. Fan and partners have shown that the conflict network is highly heritable [20]. Performance in resolving conflict observed in the ANT relates to two dopamine genes [21].

The attention network test (ANT) provides a measure of the efficiency of the alerting, orienting, and executive attention networks [19]. The unique activation and time courses of the 3 attention networks have also been demonstrated in recent cognitive neuroscience studies [16,18,32]. There is substantial functional overlap among the 3 attentional networks [18,28]. Thus, the focal brain-damaged groups were involved in this study to verify the probable anatomical separability of the three attention networks using the ANT task.

Finally, to minimize the potential confound of brain damage, we took the temporal lobe lesion group into account as brain damaged controls for this domain was not involved in any of the 3 networks.

2. Methods

2.1. Participants

Sixty-eight patients with focal brain lesions confirmed by two neurologist diagnosis were recruited from the First Hospital of Anhui Medical University, between February 2006 and April 2011. The sites of the lesions were documented by means of CT or MRI scans using the lesion overlap technique by MRIcro [6,29] (see Fig. 1).

Inclusion criteria were as follows: (1) the presence of a focal lesion confined to the frontal lobe (FL), temporal lobe (TL), or parietal lobe (PL) with a disease course ranging from 2 months to 24 months; (2) a physical condition that allows participation in the ANT task; (3) absence of childhood-onset epilepsy (late-onset seizures arising from the lesion were allowed); (4) absence of severe aphasia; (5) absence of neglect or hemianopsia; and (6) absence of other significant neurological and psychiatric disorders.

All patients who were admitted to the hospital during the recruitment period, met the inclusion criteria, and consented to participate in the study were included. Patients with tumors were examined post-surgically after a period long enough to avoid the presence of a “mass effect.” The mini-mental state examination (MMSE) was used to measure general cognitive function; Self-Rating Depression Scale was used to exclude depression. Patients were not on anticonvulsant medications at the time of testing.

Fifty-eight age-, sex-, and intellectual level-matched healthy controls (HC) without a history of neurological or psychiatric disorders were recruited and compensated for their participation. Patients and healthy controls were all right-handed. The details are presented in Table 1.

The study was approved by the Ethical Committee of Anhui Medical University (Hefei, PR China). Written informed consent was obtained from all participants.

Table 1
Demographic information, clinical data, and neuropsychological background test scores of patients with brain lesions and healthy controls (HC).

Characteristic	FL lesion patients	PL lesion patients	TL lesion patients	HC
Number of participants	27	21	20	58
Age at testing, years (mean ± SD)	35.6 ± 12.5	37.6 ± 18.1	38.6 ± 16.9	36.3 ± 13.9
Range	(15–55)	(11–62)	(17–68)	(18–67)
Gender (F/M)	17/10	12/9	13/7	34/24
Education level (years)	9.2 ± 2.9	6.7 ± 4.6	8.4 ± 3.8	8.4 ± 3.4
Range	(0–15)	(0–18)	(0–17)	(0–15)
MMSE, mean ± SD	28.6 ± 1.5	27.5 ± 1.9	28.1 ± 1.6	28.9 ± 1.2
Self-Rating Depression Scale, mean ± SD	32.5 ± 5.0	31.6 ± 4.7	30.9 ± 4.0	30.6 ± 4.2
Lesion volume, mean ± SD (cm^3)[a]	17.7 ± 11.2	10.3 ± 4.4	11.1 ± 5.7	–
Range	(3–50)	(3–18)	(1–20)	
Interval between lesion occurrence and neuropsychological evaluation (days)	179	162	145	–
Range	(39–467)	(28–490)	(20–560)	
Etiologies: tumor removal/hematoma or infarction/arteriovenous malformation/abscess or kystis	12/9/4/2	10/7/2/2	9/7/1/3	–
Left lateral/right lateral	14/13	6/15	9/11	–

[a] Lesion volume is equal to long multiplied by the width multiplied by the number of layers, according to the maximum level of lesions in the CT/MRI scan.