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Review article

Integrative parietal cortex processes: Neurological and psychiatric aspects

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ABSTRACT

For many decades the parietal cortex (PC) has been considered the key area in tasks which involve the integration of different stimuli. PC is fundamental to determine spatial sense, information navigation and integration, and is involved in several aspects of the complex motor repertoire and in neurological and psychiatric disorders. In this review, we focus on seven different aspects of PC: (i) neuroanatomy of the parietal cortex; (ii) sensory motor integration processes; iii) hand movement control: reaching, grasping, and pointing; (iv) saccadic eye movements; (v) movement observation; (vi) neurological aspects: ataxia, autism and Parkinson's disease; and (vii) psychiatric aspects: schizophrenia, bipolar disorder and depression. Among these, we related the perspectives which involve the functions of the parietal cortex and mirror neurons and that seem to play a fundamental role in action prediction, planning, observation and execution. Furthermore, we focused on the relationship between posterior parietal cortex (PPC) and hand-guided movements. For this review, we conducted an academic paper search which fulfilled the objective of the study. We conclude that the PC has great participation in different motor functions and neurological/psychiatric disorders.

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1. Introduction

The parietal cortex (PC), which in the past was considered part of the 'associative cortex', integrates information from different sensory sources [1]. Tracts from two or more sensory systems are integrated by the posterior parietal cortex (PPC) and this multimodal association area is responsible for some types of perceptions, such as space dimension and action guiding. Neuroanatomically speaking, the parietal cortex is a part of the brain located above the occipital lobe and behind the frontal lobe [2]. The parietal lobe includes the PPC as well as the dorsal stream of the visual system; thus, this cortex region can map objects perceived visually into body position coordinates [3]. Several experiments with primates have established a link between different parietal areas and a particular type of cognitive motor control [4]. The intra-parietal sulcus, for example, has been associated with saccadic eye movement and attention processes [5]. Differently, the intra-occipital parietal junction and the medial-occipital parietal junction are related to movement execution [6]. Therefore, the parietal cortex participates in several aspects of motor action, since early object identification and selection of the best parameter for the proper action, until the final stage of executing it precisely. Considering this, the present review focuses on different aspects of the parietal cortex: (i) neuroanatomy of the parietal cortex; (ii) sensory motor integration processes; (iii) hand movement control: reaching, grasping, and pointing; (iv) saccadic eye movements; (v) movement observation, (vi) neurological aspects: ataxia, autism and Parkinson's disease; and (vii) psychiatric aspects: schizophrenia, bipolar disorder and depression. In order to answer these questions, we developed a strategy for searching studies in the main databases. The computer-supported search used the following databases: Scielo, Pubmed/Medline, ISI Web of Knowledge, PsycInfo and Cochrane Library. The search term parietal cortex was associated with: neuroanatomy, saccadic eye movement, sensory motor integration, reaching, grasping, pointing, ataxia, autism, Parkinson's disease, schizophrenia, bipolar disorder and depression. In addition, we included all report reviews, meta-analyses and controlled randomized clinical and open label trials. Thus, the aim of this review was to extract relevant information supporting the idea that the parietal area is a key element to understand how the central nervous system (CNS) is able to code different motor and sensory features in healthy and pathological instances.

2. Methodology

We conducted a search focusing on articles written in English from 1980 to the present day (i.e., thirty three years); only researches conducted with people and case-report or original articles were included. Thus, for this integrative review we employed the following search terms: neuroanatomy, sensory motor integration, reaching, grasping, pointing, saccade eye movement, movement observation, sensory–motor transformations, stroke, ataxia, autism, Parkinson's disease, schizophrenia, bipolar disorder and depression. In our research we combined the term "parietal areas" with the afore-mentioned terms and we only selected the articles that reported the parietal areas as search term. The results were then manually reviewed and the articles were considered for analysis; their relevance was determined by our consensus and by overall manuscript quality.

3. Results

We selected 35 articles with the combination of the terms "parietal areas" and "neuroanatomy"; 14 articles with "parietal areas" and "sensory motor integration"; 12 articles with "parietal areas" and "reaching, grasping, pointing"; 18 articles with "parietal areas" and "saccade eye movement", 33 articles with "parietal areas", and "movement observation and sensory–motor transformations"; 69 articles with "parietal areas" and "stroke, ataxia, autism and Parkinson's disease", 59 articles with "parietal areas" and "schizophrenia, bipolar disorder and depression". After this selection, we used 164 articles which fulfilled the objective of the study.

3.1. Neuroanatomy of the parietal cortex

The parietal cortex is an associative structure fundamental for sensorimotor integration processes; its sub-areas are responsible for different functions involved in sensory processing, memory, attention and movement anticipation [7,8]. It is located behind the frontal lobe and above the occipital lobe. The primary and secondary somatosensory cortices SI and SII (Brodmann areas 1, 2, 3 and 5) are found immediately behind the central sulcus, and between this and the posterior parietal cortex (see Fig. 1). The primary somatosensory cortex (SI), located in the postcentral gyrus, is the main sensory receptive area for the sense of touch, well known as the sensory homunculus, the space where the brain represents the body [9] (see Fig. 1). It is important to note that visual stimuli that imply touch have also been observed to activate the primary somatosensory cortex [10]. Secondary somatosensory cortex (SII), firstly described by Adrian as a second cortical representation of the cat's feet [11] is located in humans in the parietal operculum. Maps of the body surface in somatosensory cortex are highly plastic; distinct patterns of sensory use or disuse are continually reconfigured altering the homuncular maps [12,13].

The PPC has sub-divisions that are addressed in different ways. At first, the intra-parietal sulcus divides the PPC in superior (SPL) and inferior parietal lobules (IPL) (see Fig. 2). The intra-parietal sulcus is divided into angular gyrus, supramarginal gyrus and the edge of the superior temporal gyrus, known as temporo-parietal junction. In turn, the angular gyrus, which corresponds to Brodmann area 39, is divided into anterior and posterior regions, while the supramarginal gyrus corresponds to Brodmann area 40 and is subdivided in at least five areas [14,15] (see Fig. 1). The PPC is connected to the primary visual cortex, a path well known as 'the dorsal stream' of visual information, an occipito-parietal network dedicated to the processing of spatial information: the 'where' pathway [16,17]. Notwithstanding, in spite of sub-regions in the human SPL and intra-parietal sulcus contributing to spatial functions, there are evidences that the human IPL fits easily into either the dorsal or ventral streams (the latter being responsible for object identification, the 'what' pathway) [17,18]. The authors suggest that the IPL is part of a flexible system that alternates between these two modes of operation, according to current behavioral demands. Indeed, damage to the right IPL contributes to hemineglect, a syndrome characterized by lack of awareness of one side of the body and space that follows lesions to this region [17]. The angular and supramarginal gyri have a fundamental role in reading and writing. Transposition of Japanese