About turn:

Neural mechanisms underlying visual processing of rotated letters and digits

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Abstract

This thesis explores neural activity associated with processing of rotated alphanumeric characters, focusing particularly on linear and quadratic trend components of orientation-dependent activity. Choice of these components was driven by results of reaction-time (RT) studies; judging whether characters are normal or backward (parity task) typically elicit RTs that are linearly related to character disorientation, implying mental rotation of the characters to the upright, while judging whether they are letters or digits (categorisation task) elicits RTs related nonlinearly to disorientation, combining both linear and quadratic component, but not indicative of mental rotation. In Experiment 1 neural activity was monitored using fMRI while participants performed these tasks. In the next two experiments, neural processing was monitored with high-density EEG. In Experiment 2 participants performed the same two tasks, while in Experiment 3 they performed the category task and red-blue colour judgements.

In Experiment 1, linear increases in fMRI activation were elicited only by the parity task and were observed in the posterior portion of the dorsal intraparietal sulcus and lateral and medial pre-supplementary motor areas, suggesting a fronto-parietal network underlying mental rotation. Experiment 2 showed that linear increases in parietal negativity between 350 and 710 ms only evident in the parity task, again indicating that mental rotation is only elicited by that task. Contrary to previous evidence, Experiment 2 indicated that both hemispheres may be involved in mental rotation, but rotation is faster in the right hemisphere than in the left hemisphere.

Experiment 1 also showed that effects of orientation common to both tasks were best characterised by a quadratic trend, and were restricted to the supramarginal gyrus. This activation was interpreted as representing orientation-dependent shape recognition. Experiments 2 and 3 also revealed orientation-dependent neural activity at three distinct stages prior to mental rotation. First, on the P1 component, there was a difference between oblique and vertical orientations, suggesting the extraction of orientation based on axis of elongation. Next, orientation affected the N1 component, with longer latencies and larger amplitudes with misorientation, and smaller effects for inversion than for intermediate angular rotations. Finally, changes in orientation affected the P2 component differently for the parity and category tasks, probably signalling the perception of orientation relative to a parity-defined memory representation, and serving as a preparation for mental rotation.

These experiments identify both the orientation-specific neural processing that occurs prior to the onset of mental rotation, and the subsequent neural correlates of mental rotation itself.

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List of Abbreviations

AC-PC line = Plane defined by Anterior Commissure-to-Posterior Commissure line
BA = Broadmann Area
BOLD = Blood Oxygenation Level Dependent
dIPS = dorsal intraparietal sulcus
dIPSa = dorsoanterior Intraparietal Sulcus
dIPSm = dorsomedial Intraparietal Sulcus
DLPFC = Dorsolateral prefrontal cortex
EEG = Electroencephalography
EPI = Echo Planar Imaging
ERP = Event-Related Potentials
FDR = False discovery rate
FFG = Fusiform Gyrus
fMRI = functional Magnetic Resonance Imaging
FOV = Field of View
FWE = Family wise error
FWHM = Full Width at Half Maximum
GDS = Global Dissimilarity Score
GFP = Global Field Power
GLM = General Linear Model
IFG = Inferior Frontal Gyrus
IPL = Inferior Parietal Lobule
IPS = Intraparietal Sulcus
ITG = Inferior temporal gyrus
LOC = Lateral-occipital complex
LP = Late Parietal
LQ = Laterality Quotient
MEG = Magnetoencephalography
MNI = Montreal Neurological Institute
MOG = Middle occipital gyrus
N1 = First negative deflection in a VEP complex, around 150 ms
P1 = First positive deflection in a VEP complex, around 100 ms
P2 = Second positive deflection in a VEP complex, around 200 ms
PET = Positron Emission Tomography
PPC = Posterior parietal cortex
pre-SMA = Supplementary Pre-Motor Area
RT = Reaction Time
SMA = Supplementary Motor Area
SMG = supramarginal gyrus
SPL = Superior Parietal Lobule
SPM = Statistical Parametric Mapping
TE = Echo Time
TMS = Transcranial Magnetic Stimulation
TR = Time to Repetition
VEP = Visual-Evoked Potentials
vIPS = ventral Intraparietal Sulcus

List of Conference Abstracts

Some of the material in this thesis was presented at the following conferences:

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