UNIVERSITÀ CATTOLICA DEL SACRO CUORE

DOTTORATO DI RICERCA IN PSICOLOGIA

CICLO XXIII

S.S.D.: M-PSI / 02

VISUAL MENTAL IMAGERY AND PERCEPTION IN SUBJECTS WITH ACQUIRED BRAIN DAMAGE

COORDINATORE: CHIAR.MO PROF. CLAUDIO ALBINO BOSIO

TESI DI DOTTORATO:
SERENA OLIVERI
MATR. 3610981

ANNO ACCADEMICO 2009/10

SUMMARY

1 **MENTAL IMAGERY** **8**
  1.1 WHAT MENTAL IMAGERY IS 8
    1.1.1 Experience or Representation? D*ifferent Meanings of Term "Imagery"* 9
    1.1.2 Does Imagery Really Exist? 11
  1.2 IMAGERY IN COGNITIVE SCIENCE 13
    1.2.1 *Allan Paivio's* Dual Coding Theory 14
    1.2.2 *Mental imagery in Jean Piaget's perspective* 16
2 **HISTORICAL DEBATES ON MENTAL IMAGERY** **18**
  2.1 THE ANALOG-PROPOSITIONAL DEBATE 18
    2.1.1 Propositional Theory 19
    2.1.2 The Quasi-Pictorial Theory 19
  2.2 THE SUPREMACY OF PICTURE THEORY AND BASIC FUNCTIONAL THEORIES 21
3 **MODELS AND COMPONENTS OF IMAGERY** **23**
  3.1 KOSSLYN'S MODEL 23
  3.2 THE MENTAL SCANNING 25
  3.3 MENTAL ROTATION 28
  3.4 MENTAL IMAGERY AND MEMORY 31
    3.4.1 Visuo-spatial working memory 32
    3.4.2 Mental imagery in thought processes 33
    3.4.3 Conclusions 35
4 **RELATIONSHIPS BETWEEN IMAGERY AND PERCEPTION** **36**
  4.1 IMAGERY AND PERCEPTION 36
  4.2 CHARACTERISTICS OF EQUIVALENCE 38
    4.2.1 The McCollough Effect 38
    4.2.2 Interference between perception and imagery 40
    4.2.3 Facilitating effects between imagery and perception 41
  4.3 THE STAGES OF VISUAL INFORMATION PROCESSING AND THE RELATIONSHIPS WITH IMAGERY 42
5 **NEURAL CORRELATES OF MENTAL IMAGERY** **44**
  5.1 IMAGERY AND PERCEPTION DOMAINS 45
    5.1.1 Shape domain 45
    5.1.2 Color domain 46
    5.1.3 Faces domain 47
    5.1.4 Orthographic material domain 48
    5.1.5 Spatial domain 48
  5.2 FUNCTIONAL LOCALIZATION AND COGNITIVE PROCESSING STREAMS 49
    5.2.1 Neural correlates of imagery and perception domains 51
    5.2.2 Studies on brain damaged subjects 54
    5.2.3 White matter networks 56
    5.2.4 Conclusions 59
6 **IMAGERY AND PERCEPTION IN SUBJECTS WITH ACQUIRED BRAIN DAMAGE** **60**
  6.1 BATTERY FOR IMAGERY AND PERCEPTION: A CLINICAL APPLICATION 60
    6.1.1 Participants and method 61
      6.1.1.1 Phase 1 61
      6.1.1.2 Phase 2 62
    6.1.2 The battery 64
    6.1.3 Procedure 67
    6.1.4 Results 67
      6.1.4.1 Analysis of age, gender and education influence in healthy subjects. 67
      6.1.4.2 Analysis of age, gender and education influence in patients 68
      6.1.4.3 Analysis of "pathology" factor influence 68
      6.1.4.4 Correlations among visual perception and mental imagery tests in each domain 68
      6.1.4.5 Correlations between mental imagery subtests within each domain 69
      6.1.4.6 Correlations between mental imagery tasks in different domains 69

6.1.4.7 Performances in mental imagery and perception test according to cognitive deficit and lesion site ... 70
6.1.4.8 Sensibility and specificity of each test ... 70
6.1.5 Discussion ... 71
6.1.5.1 Correlations between mental imagery tasks in different domains ... 73
6.1.5.2 Scores analysis of imagery/perception tests, cognitive disease and lesion site ... 74
6.1.5.3 Diagnostic value of BIP tasks ... 74
6.1.6 Conclusions ... 75
7 COGNITIVE STYLES IN BRAIN DAMAGE AND COGNITIVE DEFICIT ... 82
7.1 MENTAL IMAGERY AND COGNITIVE STYLES ... 82
7.1.1 Visualization and verbalization in mental cognition ... 83
7.1.2 Visualization and verbalization in brain lesioned patients ... 84
7.2 COGNITIVE STYLES IN PATIENTS ... 85
7.2.1 Participants ... 86
7.2.2 Method ... 86
7.2.3 Procedure ... 88
7.2.4 Results ... 88
7.2.5 Discussion ... 92
7.2.5.1 Relationship between cognitive style and cognitive deficits ... 92
7.2.5.2 Relationship between cognitive style and lesion site ... 94
7.2.6 Conclusions ... 95
8 WHITE MATTER DISCONNECTION AND IMAGERY/PERCEPTION SKILLS ... 100
8.1 NEUROIMAGING TECHNIQUES ... 100
8.1.1 Diffusion Tensor Imaging (DTI) ... 101
8.1.2 Tractography ... 103
8.2 WHITE MATTER CORRELATES OF MENTAL IMAGERY ... 103
8.3 MATERIAL AND METHODS ... 104
8.3.1 Participants ... 104
8.3.2 MRI scans and sequences ... 105
8.3.2.1 Dual-echo turbo spin echo ... 106
8.3.2.2 3D TI-weighted MP-RAGE ... 108
8.3.2.3 Diffusion-weighted Echo Planar Imaging (EPI) ... 108
8.3.3 Post processing protocol of conventional MR data ... 110
8.3.4 Post processing protocol of DTI data ... 113
8.3.5 DT computation and Tractography ... 115
8.3.5.1 Ttractography reconstruction ... 117
8.3.6 Tractographic reconstruction of peripheral fasciculi ... 118
8.3.6.1 Inferior fronto-occipital fasciculus (IFOF) ... 118
8.3.6.2 Inferior longitudinal fasciculus (ILF) ... 119
8.3.6.3 Uncinate fasciculus (UF) ... 121
8.3.7 Atlas construction ... 122
8.3.8 DT-derived indices computation ... 122
8.4 CORRELATIONS BETWEEN WHITE MATTER STREAMS AND BIP PERFORMANCES ... 123
8.4.1 Case report patient 1 ... 123
8.4.1.1 BIP performances ... 124
8.4.1.2 Impaired white matter streams ... 126
8.4.1.3 Conclusions ... 128
8.4.2 Case report patient 2 ... 128
8.4.2.1 Bip performances ... 128
8.4.2.2 Impaired white matter streams ... 129
8.4.2.3 Conclusions ... 130
8.4.3 Case report patient 3 ... 130
8.4.3.1 BIP performances ... 131
8.4.3.2 Impaired white matter streams ... 131
8.4.3.3 Conclusions ... 133
8.4.4 Case report patient 4 ... 133
8.4.4.1 BIP performances ... 133
8.4.4.2 Impaired white matter streams ... 134
8.4.4.3 Conclusions ... 134

8.4.5 Discussion 134
8.4.6 Conclusions 136

Introduction

If, before leaving home, we realize that we do not have our wallet in the bag and do not remember where we put it, what we can do is to produce a series of mental images in order to remember where we can find what we lost. Some authors claimed that mental images are the real "inhabitants" of the mind. Aristotle, in De Anima, affirmed that "the thought is impossible without an image". Nevertheless both the history of philosophy and the history of psychology, particularly the experimental psychology, showed that mental imagery is one of the most controversial and widely discussed topics. As regard psychology, the first arguments on imagery were proposed by Wundt's structuralist school in Leipzig, which stated the image is a mental epiphenomenon resulting from the sum of simple processes of thought; and on the other hand Brentano's Würzburg school drew attention to the intentionality of psychic phenomenon, where each act, such as mental imagery has a content and is destined for something. Then, until the end of the 1970s, psychology passed through a long period of disinterest for imagery, because the behaviourist movement closed each psychic phenomenon inside the "black box". With Cognitivism the discussion on imagery resurfaced with strength and took the resemblance of the opposition between picture and propositional theories. The first ones (Paivio, Kosslyn and Shepard) supported the analog theory of mental imagery, a theory that foresaw a complementarity between visual and imaginative process. These authors demonstrated that during an act of perception or imagery similar brain areas are activated and that they seemed to have similar functional properties. The other authors (Pylyshyn, Hinton), by contrast, argued that mental images are supported by propositional representations, structural descriptions, and then they are by-products of rules and propositions, symbolically coded. Afterwards the debate moved toward defining the components of the imagery and the relationships between imagery and visual perception.

Is imagery an analogous of perception? Researchers examined the differences between perception and imagery and postulated that they are different. They developed models about generation and manipulation of visual images and percepts. In Kosslyn's theory (1994), for example, working memory is very important: in this model the visual buffer activates visual mental images induced by stored information. Inputs from the eyes induce a pattern of activation during the perceptual process. The relations among external objects, which are preserved in perception, are also preserved in imagery, even though not necessarily in a concrete way. Information about objects is depicted and manipulated in a 'visual buffer' (a sort of working memory), namely, a mental space for manipulating, scanning and inspecting visual images. Attention can be shifted in the visual buffer so that people can scan visual mental images, even when their eyes are closed. Further they scan the mental image, the more time is required.

Neuropsychological investigation about the cerebral correlates of mental imagery includes both studies on brain-damaged subjects and psycho-physiological measures in normal subjects. By studying patients with brain damage we saw that perceptual impairments are often associated to limitations in the ability to create images (Farah 1988, 2000). Patients, who have lost the ability to recognize certain classes of objects, often have difficulties in generating mental images of the same objects. Instead, patients who have suffered damage in the right temporo-parietal lobe and had hemispatial neglect cannot see objects on the left side of their visual field or see the left side of the objects. Asking them to visually remind an environment, familiar to them before the neural damage, you saw that they describe only those objects that are located on the right side (Bisiach and Luzzatti, 1978). Asking them to imagine the environment looking from the opposite side, they described only those objects that were previously excluded. Again, a brain damage involves both visual perception and the construction of mental images. In recent literature we found, however, cases of double dissociation, in which perceptual functions are preserved and those imaginative impaired or, vice versa, there are damaged perception functions but intact imaginative capacity. These cases of double dissociation between perceptual and imagery skills have frequently been traced back to Kosslyn’s model (1994).

In this dissertation we aim to investigate the relationships between perception and imagery in patients with brain damage, in 5 different domains, also identified in literature (Georg Goldenberg, 1993, suggested the existence of at least five kinds of visual entities whose imagery can be independently affected by brain damage):

shapes of objects, color of objects, recognition of faces, recognition of orthographic material, recognition of spatial relationships.

In the first study the aim was to explore mental imagery and visual perception skills in patients with brain injury through a battery of tests developed by Bachoud-Lèvi, Bartolomeo, Chokron in 2001, and readapted for the Italian sample by Antonietti, Oliveri, Incorpora et aal (2008). In a second study we investigated the relationships between imagery test performance and visualizer/verbalizer cognitive style, detected by proposing 2 questionnaires (VVQ and QSVV). Finally in a third study, through instrumental investigations (DTI, TAC, MRI) in a group of patient with focal damage and specific imagery deficit, we aimed to correlate imagery and perception deficits to corresponding impairment in neural correlates.