Verbalizer-Visualizer Style in Brain-lesioned Patients: Does Rehabilitation Matter?

Chiara Incorpora[1], Gianluca Sala*, Serena Oliveri°*, Alessandro Antonietti*[1], Annalisa Risoli°

° "Don Carlo Gnocchi ONLUS" Foundation, IRCCS Santa Maria Nascente, via Capecelatro 66, 20148, Milan, Italy

* Department of Psychology, Catholic University of the Sacred Heart, Largo Gemelli 1, 20123, Milan, Italy

[1]alessandro.antonietti@unicatt.it

Abstract- **The paper aims at investigating the tendency to rely on both verbal or visual representation and strategies in patients recently affected by brain injuries and to assess the role of rehabilitation treatment in modulating such a tendency. Thirty patients were administered self-report questionnaires measuring the verbalizer-visualizer style within six months from the traumatic event and the rehabilitation training they followed was taken into account. Results showed that deficits in memory and executive functions, and mainly in visual-spatial cognition, reduced the tendency toward visualization. Such a reduction was prevalently associated to lesions in the right hemisphere. No difference was found according to treatment (motor, occupational, logopedic and neuropsychological rehabilitation). Findings stress time passed from the triggering event as the critical factor influencing cognitive style and rehabilitation efficacy.**

Keywords-Cognitive Styles; Imagery; Verbalizer; Visualizer; Brain Lesion; Cognitive Rehabilitation

I. INTRODUCTION

When individuals process information in everyday-life situations, two main kinds of cognitive representation and strategies can usually be used: verbal and visual. When a task can be carried out by using both verbal or visual representation and strategies, people consistently choose one mode over the other. Richardson [1] was the first author who proposed that a person can be classified as either a "verbalizer" or a "visualizer", defining the verbalizer-visualizer distinction as a cognitive style, namely the distinctive way of apprehending, transforming, and utilizing information. The preference or tendency to rely on a specific cognitive style is independent from the ability to apply the type of representation it involves [2, 3, 4]. In fact, in some cases the choice between the two kinds of representation and strategies depends also by affective, personality and motivational factors, as well as on experience and training [5].

Kozhevnikov, Kosslyn and Shepard [6] stressed that mental visualization is not a homogeneous dimension. Two types of visualizers were identified: "object imagers", who tend to construct colourful and high-resolution mental images; "spatial imagers", who tend to use visual representations to perform complex mental operations and to elaborate spatial relations. This distinction is supported by two brain imagery subsystems which are anatomically and functionally distinct. The ventral system is specialized in processing the objective properties of pictures such as colour, form and dimension, whereas the dorsal system is specialized in elaborating spatial attributes of stimuli and in localizing objects [7]. Lesions in the temporal cortex disrupt performance in "objective" tasks, whereas lesions in the parietal lobe affect performance in "spatial" tasks.

Despite the above mentioned associations with the alleged neurobiological bases, unexpectedly the verbalizer-visualizer cognitive style has been poorly investigated in subjects with brain injuries. After a pilot study [8], Incorpora and coworkers [9] found that patients who had been affected by neglect showed a higher tendency toward mental visualization than patients with other kinds of cognitive impairment and that attention and memory deficits induced patients to rely on the verbal style. Moreover, the visual style was less present in patients with bilateral brain damages as compared to patients with focal lateralized lesions [10]. A limit of these previous studies was that patients' cognitive style was assessed a long time after the triggering event (from 1 to 3 years) and that precise data about possible rehabilitation treatments followed by the patients were not available.

The goal of this investigation was to deepen the analysis of the verbalizer-visualizer style of brain-damaged patients by assessing cognitive style not so far from the triggering event, so as to check what extent brain lesions affect the tendency toward verbalization and visualization before spontaneous, long-term restorative processes and reorganization/ compensation processes in cognitive functioning occur. Taking into account the kind of rehabilitative training the patients had been submitted to, this paper checked to what extent it influences individual cognitive style.

An additional goal was to assess, beside the general tendency toward visualization as opposed to verbalization, also the distinct and more precise tendency to be object versus spatial imagers.

II. METHODS

A. *Participants*

Thirty brain-damaged patients took part in this study. The sample, which was totally different from that previously investigated [9, 10], was recruited in the Don Gnocchi Onlus-Foundation, S. Maria Nascente hospital in Milano, Italy. The inclusion criteria were the following: identified brain lesion; age higher than eighteen years old; no psychotropic or steroid treatment for at least one month; less than six months had passed from the triggering event. Potential patients were excluded if they showed severe deficits in vision, hand use and verbal comprehension.

All patients were submitted to a clinical exam and to a neuropsychological assessment consisting in a wide set of standardized tests devised both to exclude the presence of mental deterioration and to identify the specific cognitive impairment affecting them. This led us to classify patients on the basis of six kinds of deficits in cognitive functioning: attention deficits, memory deficits, executive function impairment, deficits in visual-spatial cognition, language deficits (aphasia) and apraxia. More than one kind of deficit might occur in the same patient.

Lesion sites were identified through a standard neurological exam and through neuro-imaging techniques as MRI and PET. Patients were categorized according to the lateralization of the lesions: ten patients had focal right lesions, eight focal left lesions and twelve bilateral lesions. The distribution of cognitive impairments and lesion sites is reported in Table I.

TABLE I DESCRIPTION OF THE SAMPLE ACCORDING TO COGNITIVE IMPAIRMENT AND SITE OF LESION

LESION COGNITIVE IMPAIRMENT SITE

	Memory Deficit	Attention Disorder	Executive Function Impair.	Visuo-spatial Deficit	Apr axia	Apha sia
Focal right	4	6	4	5	1	4
Focal left	1	4	2	5	2	5
Bilat.l	5	8	5	1	0	4
Total	13	18	11	11	3	13

Patients had taken part in rehabilitation training for recovering their cognitive deficits. Most of them (N = 26) had been involved in a standard motor therapy, eighteen had participated in sessions of occupational therapy and logopedia therapy had been addressed to nine of them. In addition, eighteen participants had been involved in a neuropsychological rehabilitation treatment consisting in activities based on Feuerstein's Instrumental Enrichment programme and on a rational therapy protocol specifically devised to rehabilitate neuropsychological disorders by means of logic problem-solving processes [11]. This treatment was integrated with specific activities aimed at enhancing the capacity to mentally transform pictures and visual scene [12, 13] and involving mental imagery to induce, through spatial analysis, body and space movements in blind-eye modality [14]. The time duration of trainings was approximately the same for all patients.

B. *Materials*

Three self-report questionnaires were employed to assess the tendency to apply mental visualization. The Verbalizer-Visualizer Questionnaire (VVQ) is the most often employed instrument to determine if an individual is either a verbalizer or a visualizer, even though the psychometric properties of the instruments have been questioned [13,16]. The Questionario Sulle Strategie Visive e Verbali (QSVV, questionnaire on visual and verbal strategies) – which measures exclusively the habit or preference, but not the ability to rely on visual or verbal modes of thinking – was used for more specific assessment. Finally, the Object Spatial Imagery Questionnaire (OSIQ) was administered to distinguish, within the visualizer style, between object and spatial imagers.

VVQ: Richardson [1] devised this instrument by selecting items from an earlier questionnaire by Paivio [15], the Individual Difference Questionnaire (IDQ). VVQ is composed by fifteen items. Respondent is asked to answer "true" or "false" in relation to his/her habits to rely on verbal or visual processes. Score 1 is given to answers "true" to a visual item (that is, an item describing the use of a visual representation or strategy, such as visualizing mentally a friend's face: item 8) or "false" to a verbal item (namely, an item describing the use of a verbal representation or strategy, such as learning new words: item 3), whereas score 0 is given if he/she answers "false" to a visual item or "true" to a verbal item. A person is classified as "verbalizer" if he/she totalizes a score from 0 to 7 and as "visualizer" if he/she totalizes a score over 10. Respondents who totalize scores between 8 and 10 are classified as "mixed" (namely, as not having a clear preference toward the visual or the verbal style).

QSVV: it is a questionnaire devised by Antonietti and Giorgetti [17, 18] to measure the extent to which individuals habitually use visual versus verbal thinking. QSVV consists of eighteen items, with nine from the visual scale and nine from the verbal scale. For each item, the respondent evaluates on a 5-point scale (1 = totally disagree; 5 = totally agree) to what extent he/she share the cognitive habit which is described. A visual score is computed by summing up the scores of visual items (such as, "When I have to memorise a phone number, I see its digits in my mind": item 1) and a verbal score is computed by summing up the scores of the verbal items (such as: "When I ask people how to reach an unknown place, I memorise the verbal instructions they give me": item 9). A total score, measuring the preference toward the visual style, is computed by subtracting the verbal score to the visual score. Total scores between -36 and 0 leads to classify an individual as a "verbalizer", scores between 1 and 8 as a "mixed", scores over 9 as a "visualizer".

OSIQ: the questionnaire, developed by Blajenkova, Kozhevnikov and Motes [19], includes two scales. The "object scale" assesses the preference for processing pictorial images; the "spatial scale" assesses the preference for elaborating schematic images. The original version of OSIQ consists of thirty items: some items address qualitative characteristics of imagery, some items addresses spatial operations and other items addresses the preferences for certain types of representations. Respondents are asked to read each item and to rate on 5-point scale (1 = totally disagree; 5 = totally agree) to what extent the described situation is true for them.

The three questionnaires described above were administered by a trained psychologist to patients within the hospital once they had finished the rehabilitation treatment.

III. RESULTS

Firstly, correlations (Spearman's rho) between VVQ, QSVV and OSIQ scores were computed (Table II). Two statistically significant correlations were found: the correlation between VVQ and QSVV total score and between the object scale of OSIQ and QSVV total score. The spatial scale of OSIQ was not correlated with the object one, as well as with the other questionnaires. This supports the dissociation between the preference to elaborate the spatial attributes of stimuli, which may fail to involve the construction and manipulation of pictorial mental images, and the preference to process mental images which are rich of perceptual details [20].

TABLE II CORRELATIONS BETWEEN VVQ, QSVV AND OSIQ SCORES

	QSVV total	OSIQ object	OSIQ spatial
VVQ	.557 **	.021	.021
QSVV total		.543 **	-.014
OSIQ object			.120

* $p < .005$ ** $p < .001$

A series of ANOVAs were computed by assuming the presence/absence of cognitive impairments as independent variables and VVQ, QSVV and OSIQ scores as dependent variables. The apraxia group was excluded from analyses because of the low number of patients included in this category.

As far as VVQ scores were concerned, ANOVAs revealed the absence of statistically significant differences depending on the presence/absence of attention deficits, memory deficits, executive function impairments and aphasia. It is however worth noting that the higher difference in VVQ scores between patients with and without a given cognitive deficit occurred in the case of visual-spatial impairment: patients with this kind of deficit scored lower (M = 8.25, SD = 2.49) than patients without it (M = 9.09; SD = 2.20) ($F_{1,29}$ = 2.90, p < .10).

QSV scores obtained by patients with and without each type of deficit are reported in Table III. Except the case of aphasia, patients without cognitive deficits tended to use mental visualization more than patients with deficits. The differences between the two groups were rather remarkable as far as attention, executive functions and visuo-spatial cognition are concerned.

Patients with visual-spatial deficits scored (M = 50.00, SD = 13.60) significantly lower ($F_{1,29}$ = 4.21, p < .05) in the OSIQ object scale than patients without such kind of deficit (M = 39.63, SD = 14.32). No other significant difference was found in this scale. Also in the spatial scale of OSIQ no significant difference between patients with and without cognitive disorders emerged.

A series of ANOVAs were computed in order to verify possible relationships between site of lesion and verbalizer-visualizer style. Results are reported in Table IV. Patients with right lesions showed a reduced tendency to rely on visual representation and strategies in all questionnaires.

TABLE III MEAN QSVV SCORES （SD IN PARENTHESIS） IN PRESENCE/ABSENCE OF COGNITIVE IMPAIRMENTS

COGNITIVE IMPAIRMENT GROUP

	Without Deficit	With Deficit	F	p
Attention	5.25 (6.78) [N = 12]	4.38 (6.53) [N = 18]	2.901	< .10
Memory	4.75 (7.29) [N = 20]	4.70 (5.01) [N = 10]	0.002	n.s.
Executive functions	6.10 (6.81) [N = 19]	2.36 (5.51) [N = 11]	3.526	< .10
Visuo-spatial	5.22 (6.17) [N = 22]	3.37 (7.72) [N = 8]	2.963	< .10
Aphasia	4.70 (7.83) [N = 17]	4.70 (4.62) [N = 13]	0.001	n.s.

TABLE IV VVQ, QSVV AND OSIQ MEAN SCORES (SD IN PARENTHESES) ACCORDING TO THE SITE OF LESION

MEASURE LESION SITE

	Focal right	Focal left	Bilateral	$F_{2,39}$	p
VVQ	8.40 (1.95)	8.50 (2,26)	9.50 (2.54)	0.770	n.s.
QSVV	2.25 (3.77)	3.40 (6.13)	5.50 (7.63)	2.589	< .10
OSIQ Object	41.90 (13.42)	45.13 (14.18)	53.08 (13.91)	2.692	< .10
OSIQ Spatial	35.40 (9.32)	39.00 (6.04)	40.08 (9.40)	0.804	n.s.

ANOVAs were also computed to assess whether the kind of rehabilitation treatment affected patients’ cognitive style. In no case significant differences in VVQ, QSVV and OSIQ scores between patients who had followed and not followed the motor, occupational, logopedia therapies and neuropsychological training emerged.

IV. DISCUSSION

In literature cases of individuals who showed the loss of imaginative experience after brain damages are reported [21]. For instance, Bisiach and Luzzati [22] tested a patient with right hemispheric lesion who was told to imagine the buildings around a well-known monument: when the patient was mentally placed behind that monument, he described correctly the landmarks on the right side but not those placed on the left side; instead, when he was placed in front of the monument, he described the buildings placed on the left side, but not those placed on the right side as correctly described before. Thus, brain lesions can impair the ability to visualize mentally at least a part of the spatial field. However, little is know about the effects produced by brain injuries not on ability, but on the habit or preference to construct and manipulate visual mental representations. When the capacity to mentally visualize is preserved, do patients make use of such a cognitive strategy to perform every-day tasks?

Incorpora and coworkers [9] showed that persisting attention and memory deficits following brain lesions inhibit the tendency to rely on mental imagery in cognitive tasks and lead patients to prefer to employ verbal representations and strategies. However, the disposition to apply mental visualization is enhanced in patients with neglect. This might be due either to a spontaneous over-compensation process or to the rehabilitation training followed by the patients, both resulting in an increased use of imagery which had been learnt to overcome the visual-spatial impairments associated to the neural damages. Since patients’ cognitive style was assessed a long time after the triggering event, the short-time effects on the verbalization-visualization tendency remained unknown. The present study was aimed at investigating possible changes in cognitive styles in a shorter time, having also a control over the rehabilitation training carried out by patients in the meanwhile.

It was confirmed that deficits in basic cognitive processes such as attention, memory and executive functions, lead patients to adopt more verbal rather than visual ways of thinking and it was proved that this is true also if only six, or even less, months passed from the triggering event. Presumably mental imagery involves a remarkable activation of attention and memory systems; if they are impaired, people are prevented to rely on imagery to carry out cognitive tasks and tend to rely on verbal representations.

Contrary to what was observed a long time after the traumatic event, also visual-spatial deficits inhibit the recourse to mental visualization. A consistent finding which emerged across the questionnaires employed here was that patients with impairments in visual-spatial cognition obtained lower visualization scores than patients lacking of such impairments. This effect concerned only the tendency to process mentally pictorial images, namely images including rich perceptual details (as measured by VVQ, QSVV and the object scale of OSIQ), but not more abstract images as those involved in spatial reasoning (as measured by the spatial scale of OSIQ). Hence, it appears that visual-spatial deficits reduce the tendency toward the pictorial visual style in a short-time period after the bran lesions occurred, even though later such a style becomes predominant.

As far as the relationships between the verbalizer-visualizer style and the localization of the brain damages are concerned, we have to be aware that there is no any consensus on the hemispheric specialization of imagery processes. Heterogeneous findings have been reported in relation to the tasks and the quality of the imaginative experience. Deutsch, Bourbon, Papanicolau and Eisemberg [23] found an increase on cerebral blood flow in the parietal and occipital lobes of both hemispheres during a mental rotation task; Williams, Rippon, Store and Annett [24] reported an activation of both the hemispheres during a mental transformational task, so supporting Sergent's [25] claim that the most reasonable conclusion is to maintain that imagery involves both hemispheres. However, some data converge in stressing the role of the right hemisphere. For instance, Farah [26] found a higher activation of the left hemisphere when the cognitive tasks could be solved through verbal strategies, whereas the right hemisphere was more activated when the task required visual-spatial skills. Referring to the quality of the mental images, a higher activation in the right hemisphere in presence of particularly vivid and bright imagination experiences has been reported [27, 28]. Consistently with these findings, we observed that the preference toward mental visualization was lower in patients with brain lesions localized in the right hemisphere. However, time elapsing from the traumatic event is critical also for the relationships between cognitive styles and site of the brain injury. In fact, it has been reported [10] that, some years after the triggering event, the original right versus left localization of the brain lesions is not influential: only bilateral lesions reduce the tendency to apply visual strategies, leading patients to prefer the verbal style.

The participation to rehabilitation treatments fails to modify patients' cognitive style. Even the neuropsychological training, heavily based on mental imagery, did not induce patients to make use of visualization in everyday life situation. It might be that patients could not have learned the visual strategies because of the persisting impairments produced by the cerebral damage. In fact, some studies showed that only after many weeks a neuropsychological training yields long-lasting effects, so that the newly acquired skills can be applied to common activities thanks to the reorganization of the cerebral areas which were compromised by the brain damage that takes place through the disinhibition of the suppressed inputs, the empowerment of the preserved cognitive functions and the growth of dendritic and assonal neuronal connections [29].

V. CONCLUSIONS

If we consider together the results of the previous [9, 10] and present studies, we realize that time is a crucial factor in modulating cognitive styles after brain injuries. In a short time after the traumatic event, the severe, still lasting cognitive impairments affecting visual cognition (above all if associated to lesions in the right hemisphere), as well as some basic processes (attention, memory, executive functions), prevent people to rely on visual representations, so leading them to apply prevalently verbal strategies. Also rehabilitation programmes specifically addressed to train imagery processes are ineffective in contrasting the shift from the visual to the verbal style. However, later patients affected by neglect learn to use spontaneously imagery strategies to compensate deficits in visual-spatial cognition, so that the visualizer style becomes predominant.

This conclusion has implications for rehabilitation practice, suggesting that taking into account the current patient's cognitive style is important. In literature [30, 31, 32] it has been showed that visualizer and verbalizer styles interact with different tasks in order to facilitate learning. If individuals differ in their preference to interact with verbal and visual information and this has consequences for the efficacy of the trainings, the same might be true of clinical treatments. Brain-damaged patients should benefit from treatments based on a format that reflects their preferred mode of thinking. This can explain why in the present study the neuropsychological training, highly involving mental imagery, was ineffective in enhancing the tendencies toward visualization: because of the impairments in visual-spatial cognition, visualizer was not the patients' preferred style and this reduced the impact of the training.

We have to acknowledge a number of limits of the present study. Firstly, we used only self-report questionnaires. Even if these instruments permit investigators to measure individuals' styles in an easy way, they share some methodological problems [33]: for instance, responses can be influenced by social desiderability (the belief that a given cognitive style is better than another) and by the mood during the administration. Another limit depends of the size of the sample, which prevented us to compare sufficiently numerous subsamples of patients having a specific deficit and a specific localization of the lesions. Finally, since rehabilitation programmes were not mutually exclusive, we could not compare subgroups each following only a given treatment. Nevertheless, by considering that up to now attention was never paid to the issue of the role of cognitive styles in neuro-pyschological disorders and rehabilitation, this study has begun to shed light on a neglected, even though relevant, topic.

REFERENCES

[1] A. Richardson, "Verbalizer-Visualizer: A cognitive style dimension", Journal of Mental Imagery, vol. 1, pp. 119-126, 1977.

[2] F. Di Vesta, "A factor analysis of imagery tests", Journal of Verbal Learning and Verbal Behaviour, vol. 10, pp. 471-479, 1971.

[3] J. Edward and W. Wilkins, "Verbalizer - Visualizer Questionnaire: relationship with imagery and verbal-visual ability", Journal of Mental Imagery, vol. 5, pp. 137-142, 1981.

[4] C. Parrott, "Validation report on the Verbalizer-Visualizer Questionnaire", Journal of Mental Imagery, vol. 10, pp. 39-42, 1986.

[5] A. Antonietti, "Cognitive styles assessment", In Encyclopaedia of psychological assessment (vol. I, pp. 248-253), London: Sage, 2003.

[6] [6] M. Kozhevnikov, S. Kosslyn and J. Shepard, "Spatial versus object visualizers: a new characterization of visual cognitive style", Memory and Cognition, vol. 33, pp. 710-726, 2005.

[7] V. Haxby, C. Grady, B. Horowitz, L. Ungerleider, L. Mishkin, R. Carson, P. Herscovitch, M. Schapiro and S. Rapoport, "Dissociation of object and spatial visual processing pathways in human exstrastriate cortex", Proceedings of the National Academy of Sciences, vol. 88, pp. 1621-1625, 1991.

[8] A. Risoli, C. Incorpora and A. Antonietti, "Lo stile verbalizzatore-visualizzatore in soggetti con danno cerebrale focale e diffuso" [The verbalizer-visualizer style in patients with focal and diffuse brain damage], Imparare, vol. 5, pp. 67-74, 2008.

[9] C. Incorpora, S. Oliveri, M. Genevini, L. Santagostino, L. Tettamanti, A. Antonietti and A. Risoli A. (2010). "Visual and verbal styles in patients with cognitive deficits: A preliminary study", International Journal of Neuroscience, vol. 120, pp. 557-564, 2011.

[10] S. Oliveri, C. Incorpora, M. Genevini, L. Santagostino, L. Tettamanti, A. Antonietti and A. Risoli, "Clinical investigation of cognitive styles in patients with acquired brain damage", Neuropsychological Rehabilitation, in press.

[11] R. Angelini and D. Grossi, La terapia razionale dei disordini costruttivi [Rational therapy in constructive disorders], Rome: Centro di Riabilitazione S. Lucia, 1993.

[12] S. Benedan and A. Antonietti, Pensare le immagini. Schede per lo sviluppo della visualizzazione mentale [Thinking images: Activities to train mental visualization], Trento: Erickson, 1997.

[13] A. Antonietti and M. Giorgetti, "The Verbalizer-Visualizer Questionnaire: A review", Perceptual and Motor Skills, vol. 86, pp. 227-239, 1998.

[14] I. Terzi, Il metodo spazio temporale [The spatiotemporal method], Milan: Ghedini, 1995.

[15] A. Paivio, Imagery and verbal process, New York: Holt, 1971.

[16] A. Antonietti and M. Giorgetti, "A study of some psychometric properties of the Verbalizer-Visualizer Questionnaire", Journal of Mental Imagery, vol. 20, pag. 59-68, 1996.

[17] A. Antonietti and M. Giorgetti M., "Inside the verbalizer-visualizer cognitive style: Distinguishing ability, habit, and preference for the use of mental images in thought", Proceedings of the IV European Workshop on Imagery and Cognition, Puerto de la Cruz (Tenerife), pp. 222-227, 16-19 December 1992.

[18] A. Antonietti and M. Giorgetti, Pensare attraverso immagini. La misura della tendenza alla visualizzazione mentale [Thinking through images. The measurement of the tendency toward mental visualization], Milan: Vita e Pensiero, 1993.

[19] O. Blajenkova, M. Kozhevnikov and M. Motes M., "Object-Spatial imagery: A new self-report imagery questionnaire", Applied Cognitive Psychology, vol. 20, pp. 239-263, 2006.

[20] O. Blajenkova and M. Kozhevnikov, "The new Object-Spatial-Verbal cognitive style model: Theory and measurement", Applied Cognitive Psychology, vol. 23, pp. 638-663, 2008.

[21] H. Ehrlichman and J. Barrett J., "Right hemispheric specialization for mental imagery: A review of the evidence". Brain and Cognition, vol. 2, pp. 55-76, 1993.

[22] E. Bisiach and C. Luzzati, "Unilateral neglect of representational space", Cortex, vol. 14, pp. 129-133, 1978.

[23] G. Deutsch, T. Bourbon, A. Papanicolau and H. Eisemberg, "Visuo-spatial tasks compared via activation of regional cerebral blood flow", Neuropsychologia, vol. 26, pp. 445-452, 1988.

[24] D. Williams, G. Rippon, B. Stone and J. Annett, "Psychophysiological correlates of dynamic imagery", British Journal of Psychology, vol. 86, pp. 283-300, 1995.

[25] J. Sergent, "The neuropsychology of visual image generation: Data, method and theory", Brain and Cognition, vol. 13, pp. 98-129, 1990.

[26] M. Farah, "The neurological basis of mental imagery: A componential analysis", Cognition, vol. 18, pp. 245-272, 1984.

[27] D. Marks, Y. Imamura, K. Uemura and J. Tatsuno, "EEG topographical analysis of imagery", In J. McGaugh (Ed.), Contemporary psychology: Biological processes and theoretical issues, Amsterdam: Elsevier, 1985.

[28] D. Marks and A. Isaac A., "Topographical distribution of EEG activity accompanying visual and motor imagery in vivid and non vivid imagers", British Journal of Psychology, vol. 86, pp. 271-282, 1995.

[29] S. Lomber and J. Eggermont J., Reprogramming the cerebral cortex. Plasticity following central and peripheral lesion, Oxford, UK: Oxford University Press, 2006.

[30] R. Riding and E. Sandler-Smith E., "Type of instructional material, cognitive style and learning performance", Educational Studies, vol. 18, pp. 323-340, 1992.

[31] B. Grabowsky and D. Jonassen, Handbook of individual differences: learning and instruction, Hillsdale, NJ: Lawrence Erlbaum Associates, 1993.

[32] R. Riding, Cognitive styles and learning strategies: Understanding style differences in learning and behaviour, New York: Fulton Publishers, 1998.

[33] M. Hiscock, "Imagery assessment through self-report: what do imagery questionnaire measure?" Journal of Consulting and Clinical Psychology, vol. 46, pp. 223-230, 1978