Laterality in Parkinson’s disease may predict motor and visual imagery abilities

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Summary

Experimental evidence suggests that motor imagery (MI) engages the same neural substrates supporting actual motor activities and is likely impaired when such substrates are damaged, as in Parkinson’s disease (PD). MI intuitively relies on visual imagery (VI), because mental simulations of physical movements depend on the visual retrieval of these movements. Although VI is generally considered a right hemispheric function, the hemispheric dominance of MI is still in dispute. Disparities in sidedness of motor disturbances are a distinctive feature of PD, and recent findings indicate that such disparities may similarly characterize cognition. Specifically, the deficits observed may depend upon which hemisphere is principally involved. Essentially, MI and VI are cognitive tasks subject to differential impairment and reflecting the prevalence of hemispheric impairment in PD.

Motor imagery (assessed by the Vividness of Motor Imagery Questionnaire [VMIQ]) and VI (assessed by the Vividness of Visual Imagery Questionnaire [VVIQ] and Test of Visual Imagery Control [TVIC]) were examined in patients with asymmetric PD and in healthy elderly control subjects (HC group). VMIQ scores were similar in PD laterality subsets and the HC group, but VVIQ scores were significantly lower in both PD groups compared with the HC group. TVIC scores were significantly lower in the presence of left motor (right hemispheric) impairment and were predictive of left motor (right hemispheric) impairment. We suspect that MI is strongly reliant on VI and that language may mediate these two functions, to the extent that both are evoked through verbal stimuli. Working memory, both visual and verbal, is also involved in MI and VI tasks. Without due attention to laterality of symptoms, any training incorporating MI and VI may not deliver expected outcomes in the setting of asymmetric PD symptomatology.

KEY WORDS: hemispheric lateralization, motor/visual imagery, Parkinson’s disease, rehabilitation.

Introduction

Motor imagery (MI) is the mental simulation of movement within the working memory system in the absence of any real body movement (Jeannerod, 1994; Decety, 1996). It requires active retrieval of corresponding mental representations from visual memory stores, as well as their manipulation and organization. Both kinesthetic and visuospatial working memory are likely involved in the sensing of actual movements (Naito et al., 2002) and in witnessing those of others, respectively (Ruby and Decety, 2001; Keogh and Pearson, 2011). However, the quality of MI vividness changes with age as working memory declines (Skoura et al., 2005; Malouin et al., 2010). Changes in MI have also been documented in most neurological conditions, whether acute or progressive (Di Rienzo et al., 2014), including cerebrovascular lesions (Johnson, 2000), multiple sclerosis (Heremans et al., 2012), and Parkinson’s disease (PD) (Leiguarda et al., 2009).

Motor imagery is believed to engage the same neural substrates implicated in motor activities and in related sensory, kinesthetic and visual input integration (Heremans et al., 2013). Improved motor performance may therefore be expected following rehabilitation programs using MI training to facilitate neuroplasticity processes. On the other hand, the declines in MI associated with most brain pathologies potentially amenable to rehabilitation may limit the utility of this approach. In PD, in particular, the basal ganglia harbor neural substrates for sensorimotor integration, supporting both MI and actual motor output (Leiguarda et al., 2009). MI training outcomes in patients with PD have consequently been fraught with inconsistencies (Heremans et al., 2013). For example, whereas one source (Tamir et al., 2007) claimed a reduction in bradykinesia by combining MI and physical practice (so-called motor imagery practice [MIP]), other authors found no clear effect (Braun et al., 2011). Inconsistent results have also been obtained by applying MIP to action observation therapy (Caligiore et al., 2017). Differences in scales used to assess MI and motor performance, in patient selection criteria, and in experimental designs may also contribute to inconsistencies reported in the literature. In particular, the sidedness of motor disturbances, which is a distinctive feature of PD (Cronin-Golomb, 2010), suggesting that different hemi-
spheres are involved, has not received due attention in most studies. The left and right hemisphere are not involved to the same degree in MI, and this disparity should be considered when assessing pathologies characterized by asymmetric hemispheric involvement. Although the left hemisphere seems dominant for MI (Fadiga et al., 1998), experimental reports are nevertheless inconsistent in acknowledging the right hemispheric disadvantage in this regard, at least in estimates generated via reaching tasks (Johnson et al., 2001; Gabbard et al., 2005). Observations in stroke indicate differences in MI performance according to the side of the damage. For example, right (vs left) hemispheric lesions increase simulation time during MI tasks (Stearns et al., 2007; Malouin et al., 2012). Despite this incomplete agreement on MI hemispheric dominance, there is evidence of differing roles for the two hemispheres. Thus, laterality of symptoms must always be considered when assessing MI in patients with cerebral damage and when devising MI training programs.

The structural/functional asymmetries in PD could extend from deeper substances to cortical areas (Zarei et al., 2013; Pereira et al., 2014; Heinrichs-Graham et al., 2017; Tanner et al., 2017), and an increasing number of studies now indicate that cognitive functions in PD may display asymmetry as well. The hemispheric expression of cognition in PD may even interact with MI, especially in questionnaires involving word or sentence comprehension (i.e., linguistics), to retrieve visual images. It has been shown that in PD with predominance of left hemispheric involvement (right-sided motor symptoms), language and memory impairment prevail, whereas spatial attention disorders are commonly associated with right hemispheric damage (left-sided motor symptoms) (Verreyt et al., 2011). Thus, performance of MI tasks may be obscured by reliance on visual imagery (VI), which does not necessarily imply retrieval of action/movement images, and on language. However, VI is not an isolated entity. Its components may be supported by various left or right hemispheric substrates (Ehrlichman and Barrett, 1983; Kosslyn et al., 1988; Gasparini et al., 2008), even though it is customarily a function subordinated by the right hemisphere.

Our aim was to ascertain whether laterality (i.e., sidedness) of PD impairment is predictive of MI disorders. We thus investigated patients whose PD symptoms were asymmetric at presentation, either right-sided PD reflecting left hemispheric involvement (RPD-LH) or left-sided PD reflecting right hemispheric involvement (LPD-RH). We also explored a potential link between such MI disorders and a more general derangement of VI, which in turn may differentially localize hemispheric damage.

Materials and methods

Subject selection

A total of 39 patients with idiopathic PD was selected for study, all consecutively admitted between March 2015 and January 2017 to the Geriatric Day Hospital of the Policlinico Gemelli Foundation - Catholic University of Rome. Exclusion criteria were as follows: history of stroke, diagnosis of dementia, visual or hearing impairment, unwillingness to participate. PD was diagnosed as specified by the United Kingdom Parkinson’s Disease Society Brain Bank criteria. Severity of PD was gauged using the Motor Section of the Unified Parkinson’s Disease Rating Scale (UPDRS III; Fahn and Elton, 1987). All subjects received levodopa, alone or in combination with a dopamine agonist, and were evaluated in ‘ON’ dopaminergic states (i.e., normal daily medication dosage given one hour before administering questionnaires). All were right-handed, as defined by the Edinburgh Handedness Inventory (Oldfield, 1971). In addition, 14 healthy elderly subjects served as controls (HC group). Our Institutional Review Board approved the study protocol, which upheld legal requisites and international norms (Richam, 1984). Each patient provided written informed consent.

Laterality of PD patients

Laterality (i.e., the side most affected) was determined on a clinical basis, as established by UPDRS or anamnesis of sidedness at first symptom.

Motor and visual imagery assessments

Motor and visual imagery were evaluated using validated Italian versions (Antonietti and Crespi, Catholic University unpublished report, 1996) of three separate questionnaires: Vividness of Movement Imagery Questionnaire (VMIQ) (Isaac et al., 1986); Vividness of Visual Imagery Questionnaire (VVIQ) (Marks, 1973), and Test of Visual Imagery Control (TVIC) (McKelvie, 1992). The VMIQ is a measure of motor imagery, evaluating the ability to visualize the movements of others. Subjects are asked to rate transitive and intransitive movements of various body parts in retrieved images (5-point scale: 1, clear and vivid; 5, no image at all), checking appropriate boxes (maximum score, 120). In the VVIQ (maximum score, 80), subjects are asked to evaluate the vividness of static evoked mental images (4-point scale: 1, clear and vivid; 4, no image at all). The TVIC (maximum score, 50) measures the ability to control and intentionally manipulate mental images. Subjects are asked to mentally envision and transform specific scenes in various ways (e.g., modifying positions or colors), rating the difficulty involved (5-point scale: 1, unable to transform; 5, very easily transformed). Whereas the VVIQ addresses the vividness of static images, the VMIQ concerns the vividness of movements performed by others; and the TVIC tests the capacity to mentally modify retrieved images, changing the position or color of elements. All three tests were administered to the 39 test subjects and 14 healthy controls in the same order.

Covariates

Education was expressed as years of school attendance. Smoking was calculated as total lifetime pack-years for current and former smokers. Drugs were designated in accordance with the Anatomical Therapeutic Chemical Classification System, using the International Classification of Diseases (9th edition), Clinical Modification, (ICD-9-CM, World Health Organization, 2011) to code diagnoses. Comorbidity was quantified by Charlson score, and body mass index was calculated as weight (g) divided by height squared (m²). The Mini Nutritional Assessment was applied to evaluate nutritional status. The Tinetti Test served to evaluate a patient’s ability to walk and maintain balance. Physical performance was evaluated using the Short Physical Perf-
functional Battery. Ambulatory 24-h blood pressure record-
ings were obtained from the non-dominant arm, using a
properly calibrated device (Blood Pressure Monitor Sys-
tem 90217; Space Laboratories, Washington, DC, USA).
Dips were defined as nocturnal systolic blood
pressure declines <10%. Functional ability was derived
from Katz Activities of Daily Living (ADL) and Lawton
and Brody Instrumental Activities of Daily Living (IADL) scale
scores, equating functional disability with the loss of at least
two ADL points. Depressive symptoms were gauged by a
15-item Italian version of the Geriatric Depression Scale.

Disease duration was also recorded. L-dopa equivalent
daily dose was calculated using a standardized formula
and normalized for body weight (Tomlinson et al., 2010).
Cognitive performance was assessed using the Mini-Men-
tal State Examination (MMSE) and a standard neuropsy-
chological battery, including tasks of memory, attention,
language, visuospatial analysis, intelligence and praxis
(Folstein et al., 1975).

Statistical analysis
All computations relied on standard software (SPSS
v20.0 for Mac; SPSS Inc [IBM], Chicago, IL, USA), set-
ing significance at p<.050. Continuous variables were
individually expressed as mean ± standard deviation or
median with inter-quartile ranges. Analysis of variance
for normally distributed variables served to address lat-
erality of PD. Nonparametric Mann-Whitney U test
was otherwise applied, using two-tailed Fisher’s exact test
for dichotomous variables. The Kruskal-Wallis H test
with post-hoc Bonferroni correction was used to assess
group differences, comparing subsets of patients with
PD (RPD-LH vs LPD-RH) and healthy controls.

Spearman’s rank-order correlation helped to determine
the relation between MMSE and MI task scoring in all
PD (RPD-LH vs LPD-RH) and healthy controls.
subsets, whereas PD subset scores were not
significantly different. Likewise, statistically significant
differences in TVIC scores emerged in group compar-
isons (χ² (2)=10.36; p=.006). Specifically, the LPD-RH
subset differed significantly from both the HC group
(χ² = 16.89; p=.007) and the RPD-LH subset (χ² =12.21; p=.042).

In the patients overall, Spearman’s rank-order correla-
tion revealed significant but weakly positive correlations
between MMSE and VVIQ scores [r_S(53)=.311; p=.023]
and between MMSE and TVIQ scores [r_S(53)=.276;
p=.045]. Hence, the better a patient performed on the
MMSE, the better their performance on VVIQ and VMIQ.

Only a trend between MMSE and TVIC scores [r_S
(53)=.281; p=.059] was evident, but there emerged a
significant and strongly positive correlation among all
three tests (all p<.0001 and r_p>.60).

In logistic regression analysis, predominantly left-sided
motor impairment (LPD-RH) was associated with an
increased probability of poorer VVIQ scores (OR=1.08,
95% CI: 1.01 -1.17) in a crude model, after adjusting for
age and gender (OR=1.10, 95% CI: 1.01-1.21), as well
as in the multivariable model (OR=1.14; 95% CI=1.01-
1.29), adjusted for those variables showing significant
differences in univariate analyses. Again, predominantly
left-sided motor impairment (LPD-RH) was associated
with an increased probability of poorer TVIC scores
(OR=1.12; 95% CI= 1.02 -1.24) in a crude model, once
adjusted for age and gender (OR=1.13; 95% CI=1.02-
1.24), as well as in the multivariable model (OR=1.14;
95% CI=1.01-1.30), adjusted for those variables show-
ing significant differences in univariate analyses. Con-
versely, predominantly left-sided motor impairment had
no bearing on VMIQ scores in the crude model
(OR=1.04; 95% CI=.99 -1.09).

Using the same adjusted logistic model, increasing
TVIC scores were associated with an increased proba-
.bility of predominantly left-sided motor impairment (p
for linear trend=.042). However, there was no significant
trend for VVIQ scores (p for trend=.468).

The AUC values generated indicated that only TVIC
scores were useful in predicting predominantly left-sided
motor impairment (AUC=0.74), with VVIQ scores fail-
ing to discriminate between left- or right-sided impair-
ment (p=.050).

Discussion
The three questionnaires administered in the course of
this study showed high degrees of correlation, con-
firming that MI is strongly reliant on VI. In addition, signifi-
cant correlations emerged between VVIQ, TVIC and
MMSE (only a trend between VMIQ and MMSE), thus
underlining that these questionnaires correlate well with
cognitive functions. Ultimately, no groupwise differences
materialized with respect to the questionnaire on MI
(VMIQ). However, on probing the vividness of VI (VVIQ),
both PD subsets performed similarly, scoring significant-
ly below the HC group; and in the questionnaire aimed
at control of visual imagery (TVIC), the LPD-RH patient
subset performed significantly worse than the RPD-LH
subset and the HC group (the latter two performing sim-
ilarly). In short, only those patients with right hemispher-
ic damage displayed impaired control of VI; instead,
both PD subsets showed impaired vividness of VI, and
MI seemed to be regularly preserved. Once adjusted for confounding factors, logistic regression analysis indicated that lower VVIQ and TVIC scores were associated with increased probability of right hemispheric involvement (LPD-RH), although only TVIC scores proved capable of predicting such involvement. Thus the TVIC survey, which quantifies an individual’s capacity to manipulate retrieved images (mostly through mental modifications of position or color), seemed to be a particularly sensitive gauge of right hemispheric damage. Despite showing similarities in a number of clinical and neuropsychological variables, our two patient subsets differed in task performance requiring mental manipulation of retrieved images. More than imagery of body movements (MI), mental manipulation of object images may show an especially close relationship with right hemi-

### Table 1 - Characteristics of participants according to prevalent side of motor impairment.

<table>
<thead>
<tr>
<th>Demographics &amp; lifestyle habits</th>
<th>Participants with left-sided motor impairment (n=17)</th>
<th>Participants with right-sided motor impairment (n=22)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>73 (6)</td>
<td>72 (8)</td>
<td>.917</td>
</tr>
<tr>
<td>Sex (female)</td>
<td>5 (29)</td>
<td>9 (41)</td>
<td>.518</td>
</tr>
<tr>
<td>Education (years)</td>
<td>7 (5 - 8)</td>
<td>8 (8 - 18)</td>
<td>.035</td>
</tr>
<tr>
<td>Current alcohol consumption (glasses/week)</td>
<td>4 (0 - 6)</td>
<td>0.5 (0 - 5)</td>
<td>.271</td>
</tr>
<tr>
<td>Smoking (Total lifetime pack years)</td>
<td>12 (7 - 26)</td>
<td>36 (21 - 46)</td>
<td>.055</td>
</tr>
<tr>
<td>Time from Parkinson’s diagnosis (months)</td>
<td>22 (9 - 52)</td>
<td>36 (18 - 74)</td>
<td>.308</td>
</tr>
<tr>
<td>Comorbid conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>2 (12)</td>
<td>5 (24)</td>
<td>.427</td>
</tr>
<tr>
<td>Heart failure</td>
<td>1 (6)</td>
<td>0 (1)</td>
<td>.447</td>
</tr>
<tr>
<td>Chronic pulmonary disease</td>
<td>1 (6)</td>
<td>2 (9)</td>
<td>.999</td>
</tr>
<tr>
<td>Charlson Comorbidity Index</td>
<td>1 (0 - 2)</td>
<td>1 (0 - 1)</td>
<td>.954</td>
</tr>
<tr>
<td>Medications</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzodiazepines</td>
<td>2 (12)</td>
<td>1 (5)</td>
<td>.577</td>
</tr>
<tr>
<td>Neuroleptics</td>
<td>0 (0)</td>
<td>1 (5)</td>
<td>.999</td>
</tr>
<tr>
<td>Beta-blockers</td>
<td>4 (23)</td>
<td>7 (33)</td>
<td>.721</td>
</tr>
<tr>
<td>Selective serotonin reuptake inhibitors</td>
<td>4 (23)</td>
<td>5 (24)</td>
<td>.999</td>
</tr>
<tr>
<td>Total levodopa equivalent daily dose (mg/kg)</td>
<td>5.33 (2.39 - 8.03)</td>
<td>7.92 (4.78 - 12.25)</td>
<td>.048</td>
</tr>
<tr>
<td>Levodopa daily dose (mg/kg)</td>
<td>4.87 (2.12 - 6.49)</td>
<td>5.80 (3.13 - 9.18)</td>
<td>.308</td>
</tr>
<tr>
<td>Total number of drugs</td>
<td>4 (4 - 6)</td>
<td>6 (4 - 8)</td>
<td>.116</td>
</tr>
<tr>
<td>Physical performance test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unified Parkinson’s Disease Rating Scale</td>
<td>42 (29 - 56)</td>
<td>39 (30 - 55)</td>
<td>.998</td>
</tr>
<tr>
<td>Hoehn and Yahr index</td>
<td>2 (1 - 3)</td>
<td>2 (2 - 3)</td>
<td>.399</td>
</tr>
<tr>
<td>15-item Geriatric Depression Scale</td>
<td>4 (2 - 9)</td>
<td>5 (2 - 7)</td>
<td>.977</td>
</tr>
<tr>
<td>ADL disability</td>
<td>5 (29)</td>
<td>10 (45)</td>
<td>.343</td>
</tr>
<tr>
<td>IADL disability</td>
<td>9 (53)</td>
<td>16 (73)</td>
<td>.314</td>
</tr>
<tr>
<td>Tinetti test</td>
<td>22 (4)</td>
<td>18 (6)</td>
<td>.033</td>
</tr>
<tr>
<td>Mini Nutritional Assessment</td>
<td>25 (3)</td>
<td>25 (4)</td>
<td>.966</td>
</tr>
<tr>
<td>Short Physical Performance Battery</td>
<td>8 (3)</td>
<td>7 (3)</td>
<td>.230</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>27.1 (4.1)</td>
<td>26.4 (3.5)</td>
<td>.531</td>
</tr>
<tr>
<td>Abnormal dipping pattern</td>
<td>6 (40)</td>
<td>5 (24)</td>
<td>.465</td>
</tr>
</tbody>
</table>

Abbreviations: ADL=activities of daily living; IADL=instrumental activities of daily living
Motor imagery in Parkinson’s disease

Table II - Performance on neuropsychological tests in participants with prevalent left-sided (LPD-RH) or right-sided (RPD-LH) motor impairment.

<table>
<thead>
<tr>
<th>Neuropsychological tests</th>
<th>LPD-RH (n =17) mean (SD)</th>
<th>RPD-LH (n = 22) mean (SD)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini-Mental State Examination</td>
<td>26.3 (3.8)</td>
<td>26.4 (3.3)</td>
<td>.952</td>
</tr>
<tr>
<td>Temporal orientation</td>
<td>4.2 (1.)</td>
<td>4.3 (1.2)</td>
<td>.882</td>
</tr>
<tr>
<td>Spatial orientation</td>
<td>4.4 (0.5)</td>
<td>4.5 (1.3)</td>
<td>.871</td>
</tr>
<tr>
<td>Rey words immediate recall (adjusted score)</td>
<td>31.0 (15.2)</td>
<td>30.8 (12.6)</td>
<td>.984</td>
</tr>
<tr>
<td>Rey words delayed recall (adjusted score)</td>
<td>4.3 (4.1 - 10.1)</td>
<td>5.9 (5.1 - 7.1)</td>
<td>.679</td>
</tr>
<tr>
<td>Forced choice word recognition (% accuracy)</td>
<td>0.8 (0.2)</td>
<td>0.8 (0.1)</td>
<td>.807</td>
</tr>
<tr>
<td>Digit span forward</td>
<td>4.25 (0.95)</td>
<td>4.6 (1.6)</td>
<td>.277</td>
</tr>
<tr>
<td>Digit span backward</td>
<td>3.2 (1.5)</td>
<td>3.4 (1.6)</td>
<td>.817</td>
</tr>
<tr>
<td>Spatial span (Corsi test) (forward)</td>
<td>4.2 (2.0)</td>
<td>4.0 (1.4)</td>
<td>.562</td>
</tr>
<tr>
<td>Spatial span (Corsi test) (backward)</td>
<td>3.2 (1.6)</td>
<td>2.5 (1.6)</td>
<td>.486</td>
</tr>
<tr>
<td>Rey-Osterrieth copy (adjusted score)</td>
<td>20.4 (9.3)</td>
<td>19.2 (9.7)</td>
<td>.830</td>
</tr>
<tr>
<td>Rey-Osterrieth recall (adjusted score)</td>
<td>7.8 (1.2 - 15.0)</td>
<td>8.3 (4.7 - 11.0)</td>
<td>.679</td>
</tr>
<tr>
<td>Zazzo's test (hits)</td>
<td>9.5 (1.7)</td>
<td>8.2 (5.2)</td>
<td>.642</td>
</tr>
<tr>
<td>Zazzo's test (false alarms)</td>
<td>2 (0 -10)</td>
<td>2 (0 - 6)</td>
<td>.839</td>
</tr>
<tr>
<td>Object naming</td>
<td>23.6 (3.9)</td>
<td>23.6 (5.0)</td>
<td>.999</td>
</tr>
<tr>
<td>Raven Colored Matrices (adjusted score)</td>
<td>24.5 (6.2)</td>
<td>23.64 (5.34)</td>
<td>.555</td>
</tr>
<tr>
<td>Phonological Word Fluency (adjusted score)</td>
<td>24.1 (8.6)</td>
<td>23.6 (10.0)</td>
<td>.932</td>
</tr>
</tbody>
</table>

Table III - Performance on motor and visual imagery tests in participants with prevalent left-sided (LPD-RH) or right-sided (RPD-LH) motor impairment and in healthy controls (means ± SD are reported).

<table>
<thead>
<tr>
<th></th>
<th>Left-sided motor impairment (n =17)</th>
<th>Right-sided motor impairment (n = 22)</th>
<th>Healthy controls (n =14)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor and Visual Imagery Testing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual Motor Imagery Questionnaire (VMIQ)</td>
<td>86.8 (16.7)</td>
<td>97.1 (15.8)</td>
<td>101.21(14.55)</td>
<td>.082</td>
</tr>
<tr>
<td>Vividness of Visual Imagery Questionnaire (VVIQ)</td>
<td>56.5 (11.6)</td>
<td>63.8 (8.6)</td>
<td>75.28 (4.83)</td>
<td>.006</td>
</tr>
<tr>
<td>Test of Visual Imagery Control (TVIC)</td>
<td>34.2 (9.8)</td>
<td>42.6 (8.4)</td>
<td>42.14 (7.43)</td>
<td>.0001</td>
</tr>
</tbody>
</table>

spheric damage and appears to be critical in differentiating between PD subsets. Also of note, patients with a predominance of left hemispheric damage compared poorly with HCs only in terms of VVIQ performance (static mental image retrieval). However, language may also suffer in the presence of left hemispheric damage, because retrieval of mental images in this questionnaire is largely facilitated by the ability to comprehend highly complex sentences, unlike capacities targeted in the other questionnaires.

The outcomes of this study did not confirm impairment of MI tasks in patients with PD, but instead suggested that VI tasks are impaired. Although patients with right hemispheric damage showed impairment in both visual imaging questionnaires (VVIQ and TVIC), those with left hemispheric damage showed isolated difficulties in retrieval of mental images involving complex sentences. A tentative interpretation of the above is that VI requires visual working memory capacity (Bruyer & Scaliquin, 1998; Baddeley and Andrade, 2000) when the task in
question mainly requires mental manipulation of retrieved images, thus increasing spatial working memory demands. Tasks such as the TVIC are thus particularly reliant on the right hemisphere, which supports this aspect of the working memory system (Doherty and Logie, 2016). On the other hand, if complex sentence comprehension is a priority (as in the VVIQ), performance is dependent on verbal working memory capacity (Caplan and Waters, 1999), whose neural substrates are confined to left hemisphere (Vallar et al., 1997). The VMIQ (devised expressly to explore MI) also requires retrieval of visual images. However, PD subsets did not differ from the HC group in this regard. It is likely that in this task, kinesthetic imagery, evoked by word-action stimulus presentation, might partially compensate for the VI deficit.

Our interpretations are, to some extent, supported by the literature. Impaired visuospatial transformation of mental images, hampered by a deficit of spatial working memory, has been demonstrated by others in the setting of PD (Kerai et al., 2012; Leek et al., 2014). Nevertheless, there is evidence to suggest that verbal working memory may also be impaired in patients with PD (Gilbert et al., 2005). Laterality of symptoms, however, was not addressed in any of these studies.

In theory, our findings should be confirmed in patients with left or right vascular lesions, whose consequences would presumably be clearer and afford a better understanding of roles played by the two hemispheres in MI and VI tasks. The respective relationships of MI and VI with verbal and visuospatial working memory are also in need of further delineation. However, differences shown by our PD patient subsets indicate that symptom laterality is perhaps a significant variable in any subcortical neurodegenerative state.

The chief limitation of our study is that the data obtained do not allow full disentangling of MI and VI components. This could possibly be remedied by the assignment of tasks principally demanding kinesthetic (rather than visual) imagery, or at least minimizing visual components. At the same time, an extensive evaluation of visual and verbal working memory would be in order to corroborate the independent roles of various subcomponents serving MI and VI in these patients.

Furthermore, the load of working memory in tasks should be controlled in experimental designs to mitigate the impact of inherent difficulties. Unfortunately, no specific examination of verbal and visuospatial working memory was undertaken in our patient population, and only in a few of them were verbal and spatial spans set as minimum conditions for determining the adequacy of working memory.

We acknowledge that our conclusions are in part speculative. However, despite of some critical issues that prevent coherent and definitive interpretation of the results, we have established that tasks involving mental retrieval of images are hampered in patients with PD, primarily when the right hemisphere is involved. Clearly, this finding must be taken into account in rehabilitation programs designed for such patients. Without due attention, patients with asymmetric symptomatology may not respond as anticipated to training that incorporates MI and VI components. In essence, laterality is a factor in any neurodegenerative disease with subcortical damage, creating obvious clinical disparities just as in focal cortical lesions.

References


Motor imagery in Parkinson’s disease


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