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Behaviour of Motor Disabilities and Appearance of Visual Hallucinations in Patients with Parkinson’s Disease in a Virtual Environment

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Abstract. We studied 23 Parkinson’s disease (PD) non-demented patients and 15 controls in Virtual Reality (VR) environments reproducing usual daily living situations. In VR sessions, PD patients performed their actions worse than controls, in terms of time of execution in exploration and pointing, precision as objects avoiding, and in semantic incidental memory task. We observed clear differences of performances between on and off status medication, with a global worsening during off phase. Moreover, all six patients with motor fluctuations described visual hallucinations during off state, with occurrence of images not included in the virtual environment.

Keywords. Virtual Reality, Parkinson’s disease, Visual Hallucinations

Introduction

In the rehabilitative field of Parkinson’s disease (PD), it has been demonstrated that a virtual display superimposed over a user’s visual filed, augmented reality, has been shown to initiate and sustain walking [1], in function of disease severity [2]. But, even if VR originates as an useful tool, providing within a motivating context, as an effective rehabilitation intervention, can potentially present opportunities to better understand the clinical view. In a preliminary study [3], we reported PD in two patients while in VR immersion such as in the reality, difficulty in speed of action, incidental memory, orientation, and a pointing task even- despite their normal neuropsychological tests.

Aim of the present study was to evaluate the behaviour of PD patients in different stages of the disease in order to evaluate the correlation between the ability of performing virtual tasks and the severity of extrapyramidal signs.

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1. Methods

We studied 23 non-demented patients affected by PD (mean age 65.3 years, standard deviation 7.7; education 8.40 years, standard deviation 4.6; mean score UPDRS, Unified Parkinson’s disease Rating Scale, motor part 24) and 15 control subjects (mean age 62.9 years standard deviation 9.1; education 9.3 years; standard deviation 4.4).

The environments are implemented in an immersive system, including a head-mounted display subsystem, while the motion tracking is provided by a gyroscopic tracker. To provide an easy motion a two-button joystick-type input device: pressing the upper button the operator moves forward, pressing the lower button the operator moves backwards. The direction of the movement is given by the rotation of operator’s head.

The environments reproduce usual daily living situations (supermarket, Gymnasium and Kitchen) where subjects can move around and interact with the objects. The VR research protocol includes 5 phases: learning, exploration, incidental memory tasks, denomination, and pointing. Time was recorded with an external device.

In six patients with motor fluctuations (3 men, mean age 63 years and 11.6 years of education, and 3 women, mean age 70.3 years and 7 years of education), the experimental protocol was repeated four times in four consecutive weeks, in the early morning, after the first administration of L-dopa (“medication on” week 1 and 3), and without (“medication off” week 2-4), then after 12 hours, in withdraw from L-dopa therapy.

In order to test cognitive abilities required for the tasks of the VR sessions, patients were evaluated by a dedicated neuropsychological assessment battery, including MMSE, Verbal Test (Command Comprehension Test; Phrase Construction Test), Memory Tests (Rey’s auditory verbal learning test; Disillabic Span Test, Prose Memory, Corsi’s Span, Visual Memory Test), Frontal abilities test (Clock Draw Test; Phonological Verbal Fluency; Raven’s colored progressive matrices; copying drawings, Frontal Assessment Battery, Weigl’s Test; Trail Making Test A and B; Search and Attention Test; Ideomotor Apraxia Test), and Visual perception (Street Completion Test).

To compare the control’s data with those of two groups of PD patients (with and without motor fluctuations), we used a Kruskal-Wallis’ Anova, followed by a Mann-Whitney two-tailed U test. Furthermore, in order to assess the correlation between neuropsychological, clinical parameters and VR performances, a square matrix of Spearman was used. Finally, to study the differences in VR variations between medication on and off, we used a Wilcoxon’s Test. All the continuous variables were dichotomized using the median as the cut-off value. The statistical analysis was conducted employing the STATISTICA program and the significant level was predetermined at p<0.05.

2. Results

In VR sessions, PD patients performed their actions worse than the control’s, in terms of time of execution in exploration (p < 0.004) and pointing (p < 0.00016), precision as objects avoiding (p < 0.0002), ability of pointing (p< 0.006), and in semantic incidental memory task (p <0.04).
Table 1 Visual Hallucinations in six motor fluctuation patients during “off-medication” session

<table>
<thead>
<tr>
<th>Patient</th>
<th>In Gymnasium: not well-defined animals on the wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 2</td>
<td>In Gymnasium: a nest of bees with bees flying around</td>
</tr>
<tr>
<td>Patient 3</td>
<td>In Gymnasium: children sitting in desks</td>
</tr>
<tr>
<td>Patient 4</td>
<td>In Kitchen: a petrol pump</td>
</tr>
<tr>
<td>Patient 5</td>
<td>In Gymnasium: a woman is mistaken as a policeman</td>
</tr>
<tr>
<td>Patient 6</td>
<td>In Gymnasium: undefined animals on the wall and on the floor</td>
</tr>
</tbody>
</table>

No significant differences were founded in the VR’s scores between the six patients with motor fluctuations and with the other patients, although those without fluctuations showed better global performances.

Inside the group of patients with motor fluctuations, we observed clear differences in the same individual between the on and off phase during VR performances, with a worsening “during off” phase in time of exploration (p<0.02), in pointing time (p<0.02), and in the ability of pointing (p<0.04). The denomination tasks scores, as well as the incidental memory task, are better during the “on” phase.

The VR scores of PD patients resulted “not correlated” with neuropsychological findings, or clinical variables.

Much more, all six patients with motor fluctuations, in both “off- medications” sessions, described visual hallucinations (Table 1), with occurrence of images not included in the virtual environment. The “object” of the visual hallucination was never the same, in the same patient, in the same environment, or in the same location. In these patients, visual dysperceptions were never experienced in the real life.

3. Discussion

We have investigated the quality of performances of PD patients during various VR tasks session, such as environment exploration or pointing at virtual objects.

The time of execution and accuracy were the parameters of reference in the evaluation. Patients were slower and more inaccurate in all tasks, compared to the controls.

Also, even if in while performing the virtual task, it is necessary to involve the “real motor system”, such as moving the hand to command the joystick, it is reasonable to hypothesize an independent contribute of the virtual immersion “in se,” in the altered findings of PD patients. In this view, these results can be consequent of the well-known alterations of the visual-motor system.

We also found a statistically significant difference between “on-off” medication, indicating that the system principally evaluated in VR, and, not easily correlatable with the clinical view, it includes a dopaminergic function, as does the retinal visual system.

Our study has shown, therefore, that a VR environment can induce the appearance of visual hallucinations in PD patients who had never previously complained of such symptoms.

Visual hallucinations (VH) are one of the most typical symptoms among the behavioral disturbances observed in PD, affecting about one-quarter of all patients.

Various pathogenetic models have been considered to explain VH in PD, recently focusing on dyregulation of external perception and internal image production secondary to dysfunctions of the ponto-genicolo system, implicated in the control of rapid eye movement during sleep [4].
4. Conclusions

Also in VR, where real motor disabilities should be less relevant, PD patients showed significantly abnormal performances comparing with the controls. These alterations can be attributed to the bradiphrenia as well as to an altered function of a dopaminergic system, not correlatable with clinical scales, such as the retina.

This system is probably implicated in the genesis of VH as well, referred by our patients during off-medication VR immersion as a behavioral manifestation of a hypodopaminergic status, supporting an integrative model of VH, which includes the retinal dopaminergic system and the REM sleep regulatory system [5].

References