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Cognitive profile of patients with rotated drawing at copy or recall: A controlled group study

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ABSTRACT

When copying or recalling a figure from memory, some patient with dementia or focal brain lesions may rotate the drawing through ±90° or 180°. We have tried to clarify the nature of this phenomenon by investigating the cognitive profile of 22 patients who rotated the copy of the Rey–Osterrieth Complex Figure and 27 who rotated (only) the recall, and two control groups of cases with the same neuropsychiatric diagnoses, but no misorientation deficit. Brain MRI and FDG-PET images were also analysed. Predictor of rotation at the copy versus rotation at the recall was visuospatial impairment as measured by the copy of the Rey Figure; predictors of rotation at the copy versus no rotation were, again, visuospatial deficits, in addition to an abnormal performance at the task of selective attention. No specific profile of cognitive impairment distinguished patients with and without rotation at the recall. Disproportionate temporo-parieto-occipital atrophy or hypometabolism were evident in cases with misorientation of the copy, while predominant frontal abnormalities were found in cases of rotated recall. Based on these findings, rotated drawing at the copy is interpreted as a dorsal visual stream deficit, whose occurrence is more probable when attentional control is impaired. Rotation at recall seems to have a distinct, more anterior, neural substrate, but its dysexecutive nature has yet to be demonstrated.

1. Introduction

The ability to copy a drawing is a complex cognitive function involving visuo-perceptual, spatial, planning, short-term memory and visuo-motor capacities, and is also a crucial task for the neuropsychological assessment of patients with cognitive impairment (Fischer & Loring, 2004; Trojano & Conson, 2008).

Qualitative analysis of drawing performance can be as informative as quantitative scoring. One type of qualitative error that is sometimes observed at the copy or recall of drawings is rotation of the model along the orthogonal axes, through ±90° or 180°, typically with relative preservation of the figural content of the stimulus. Rotated drawing has been described with a prevalence ranging from 2.5%, in neurodegenerative disorders (Isella et al., 2013), to 11%, in stroke (Turnbull, Della Sala, & Beschin, 1997b), and sometimes reported also in psychiatric patients (Royer & Holland, 1975). Few studies have shown a higher frequency in cases of right hemisphere dysfunction (Royer & Holland, 1975; Turnbull et al., 1997b), while others did not find a firm lateralising bias (Isella et al., 2013; Royer & Holland, 1975; Solms, Turnbull, Kaplan-Solms, & Miller, 1998). Solms and colleagues (1998) also investigated the intrahemispheric locus of damage in nine patients who displayed rotation when copying and/or drawing from memory, and demonstrated that "anterior structures were involved more commonly than posterior ones". The same authors tentatively suggested, but did not put to the test, a possible account for this phenomenon, drawing it from theories of the so called *orientation agnosia* (Turnbull, Laws, & McCarthy, 1995). In patients with this condition, objects identity is preserved, while knowledge of veridical objects orientation is lost or cannot be accessed, and is replaced with a canonical orientation (Harris, Harris, & Caine, 2001; Karnath, Ferber, & Bülthoff, 2000; Turnbull, Beschin, & Della Sala, 1997a; Turnbull, Della Sala, & Beschin, 2002). Solms et al. hypothesized that rotation occurs when access to the viewer-centered representation of the model is impaired, and the figure is depicted with an orientation suggested by criteria like stability or symmetry. In reality, orientation agnosia is a consequence of selective damage to the dorsal, occipito-parietal, visual stream. The authors tried to reconcile this observation with their incongruent lesional findings by 'moving' the locus of damage associated with rotated drawing more anteriorly, to fronto-parietal connections. Recently we have described the cognitive and neuroimaging features of two small case series, one with misorientation of the *copy* and the other with misorientation at the *recall* of the Rey–Osterrieth Complex Figure (ROCF) (Osterrieth, 1944) (Isella et al., 2013).

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Rotation at copy showed a relationship with neuropsychological and functional imaging evidence of parietal dysfunction, in agreement with data on orientation agnosia. Rotation at recall seemed to be unrelated with general memory deficits, and rather be associated with visuo-constructional and executive impairment, suggesting antero-posterior dysregulation. The objective of the present study was to confirm these findings, overcoming limitations of previous investigations (Della Sala, Turnbull, Beschin, & Perini, 2002; Royer & Holland, 1975; Solms et al., 1998; Turnbull et al., 1997b), i.e. using a quantitative approach, a larger sample, a clinical control group without rotated drawing and an extensive range of cognitive measures, and considering rotation at the copy and rotation at the recall separately. We hypothesized that the two types of orientation errors would be correlated, respectively, with measures of visuoperceptual and spatial functions, controlled by the posterior parietal cortex, and with performance at spatial and executive tasks, regulated by frontal and parietal areas.

2. Methods

A neuropsychologist and a neurologist retrospectively reviewed the clinical records of consecutive outpatients and inpatients referred for cognitive assessment to our Neuropsychology Service, S. Gerardo Hospital, Monza, Italy, from January 2008 to January 2013. The study was conducted in compliance of the Helsinki declaration, received the approval of the Ethics Committee of S. Gerardo Hospital, Monza. Only cases for whom the ROCF protocol was available were taken into account. Moreover, patients were included only if they had completed our routine neuropsychological battery, including the following tests: the MiniMental State Examination (MMSE) as a screening scale of global cognition; Attentional Matrices, assessing selective attention; the Digit Span for assessing verbal short term memory, and the Rey's Auditory Verbal Learning Test (RAVLT) for verbal learning and long term memory; the Token test as a measure of verbal comprehension; letter and category fluency for evaluating lexical retrieval; the Frontal Assessment Battery, tapping executive functions such as conceptualisation, mental flexibility, motor control, prehension behaviour; Raven's Coloured Progressive Matrices (RCPM) as a task of logical reasoning. Neuroradiologist's report of Computed Tomography or Magnetic Resonance Imaging scans, and Fluorodeoxy-glucose Positron Emission Tomography (FDG-PET) when available, were appraised for presence, lateralisation and distribution of brain abnormalities. Patterns of atrophy or hypometabolism were classified as predominantly anterior, predominantly posterior, or antero-posterior, based on relative extent of involvement of pre- and post-central cortical areas. Neurological diagnoses were made by an experienced neurologist based on the results of the entire evaluation protocol and according to standardised criteria.

The administration of the ROCF followed the standard procedure (Rey, 1983), but with one single delayed recall 10 min after copy. The model was always presented with its main axis oriented horizontally, and the 'diamond' placed at the right end. The instruction not to rotate the model nor the drawing sheet was always stated explicitly. Scoring of the ROCF was also performed according to the standard procedure, but rotated drawings were scored in the upright orientation by a neuropsychologist who was blind to the group (rotation/controls) membership. Presence of rotation was evaluated independently by two neuropsychologists. Rotated drawings typically present with a complete 90° or 180° inclination; therefore only rotations of more than 45° from the model were considered proper misorientations. Misplacements within a confabulating production (e.g. drawing of a church) were not included in rotations, not being a pure orientation deficit.

Patients showing rotated ROCF were subdivided into a group with rotation at the copy (RC+), and a group with rotation only at the recall (RR+). For each of the two groups, an equal number of patients without rotation (RC− and RR−) were included as controls. They were matched for age, years of education, sex distribution, neurological diagnosis and disease severity.

Student's *t*-test or chi-square analysis were used to compare socio-demographic and clinical features of RR+ and RR+ patients, RC+ and RC− patients, and RR+ and RR− patients. Level of significance was set at $p < 0.05$, further corrected using the Bonferroni correction for multiple comparisons. The ability of cognitive measures to predict rotation behaviour was assessed with logistic regression analysis, using rotation at the copy or recall as dependent variable (yes/no) and neuropsychological test scores as predictors.

3. Results

The final study sample included 22 RC+ patients and 27 RR+ patients. Rotation occurred through −90° in 20 RC+ patients out of 22 (91%) and in 25 RR+ patients out of 27 (93%), and through 180° in two RC+ (9%) and two RR+ (7%) cases (two examples are shown in Fig. 1). The socio-demographic and clinical features of the two study groups are shown in Table 1. There was no difference in age, years of education and sex distribution. As to diagnoses, there was only a trend towards significance ($x^2 = 5.571$, $p < 0.05$) for psychiatric disorders, which were relatively prevalent in RR+ patients and absent in the RC+ group.

The RC− and RR− samples had exactly the same numerosity, sex distribution and neurological diagnoses of the corresponding rotation group (including cases with the co-occurrence of MCI and a recent acute event). Mean age and education were 73.0 ± 6.1 and 7.6 years ± 3.5, respectively, for RC− patients, and 73.0 ± 7.6 and 7.9 ± 3.3, for RR− patients.

Structural neuroimaging was available for all study participants, while FDG-PET had been performed in 18 RC+, 17 RC−, 22 RR+ and 20 RR− patients. Both exams were rated for distribution of abnormalities. There was no statistically significant intergroup difference in the overall frequency of abnormal brain imaging and asymmetric patterns of atrophy or hypometabolism, nor in the side of more severe hemispheric impairment (data not shown). See Fig. 2 for the distribution of abnormalities along the antero-posterior axis in the more focal cases of the four study groups. In the RR+ group there was a significantly lower number of cases with predominantly posterior involvement, and a significantly higher number with predominantly pre-central impairment, than among RC+ ($x^2 = 9.905$, $p < 0.001$) and RR− patients ($x^2 = 9.905$, $p < 0.001$). RC+ and RC− groups had an overlapping distribution of imaging abnormalities.

When cognitive scores were contrasted (Table 2), a significantly worse performance emerged for RC+ versus RR+ patients at the copy of the ROCF ($t = 6.304$, $p < 0.0001$), the Token test ($t = 3.645$, $p < 0.001$) and the RCPM ($t = 2.862$, $p < 0.01$). RC+ patients also obtained poorer scores than RC− patients at the copy of the ROCF ($t = -3.805$, $p < 0.0001$), as well as the digit span ($t = -2.560$, $p < 0.01$). A trend towards a significantly worse performance was also present at the RCPM ($t = -2.222$, $p < 0.05$) and Attentional Matrices ($t = 2.320$, $p < 0.05$). Cognitive scores were overlapping for RR+ and RR− patients. Recall of the ROCF had been administered only to a minority of patients who rotated the copy and was therefore disregarded in the analyses involving this group of patients.

Logistic regression analysis was performed with rotation at the copy as dependent variable (yes/no); predictors were cognitive measures that had been shown to be different between RC+ patients, and RR+ (copy of ROCF, Token test and the RCPM) and