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Research report

Tool use disorders in neurodegenerative diseases: Roles of semantic memory and technical reasoning

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ABSTRACT

In the field of apraxia, it has been suggested that the ability to use tools and objects in daily life depends not only on semantic knowledge about tool function and context of use but also on technical reasoning about mechanical properties of tools and objects. The aim of the present work was to assess tool use abilities regarding these hypotheses in patients with neurodegenerative diseases and reduced autonomy. Performance of patients with Alzheimer's disease (AD) ($n = 31$), semantic dementia (SD) ($n = 16$) and corticobasal syndrome (CBS) ($n = 7$) was compared to that of healthy control participants ($n = 31$) in familiar tool use tasks, functional/contextual associations and mechanical problem solving (MPS). A conversion method was applied to data in order to avoid ceiling effects. Tool use disorders were found in all patient groups but the underlying reasons were different. Patients with SD had difficulties in imagining and selecting familiar tools due to the semantic loss but they performed in normal range in MPS tasks. Interestingly, they performed better with only one tool and its corresponding object, which is interpreted as a partial compensation of semantic loss by spared technical reasoning. Patients with CBS exhibited the reverse

Abbreviations: AD, Alzheimer's disease (as a group); BEC, "Batterie d'Evaluation Cognitive" (a French neuropsychological battery); CBS, Corticobasal syndrome; FAB, Frontal Assessment Battery; FCA, Functional and Contextual Associations; HC, Healthy controls (as a group); MMSE, Mini Mental State Examination; MPS.C, Mechanical Problem Solving (choice condition); MPS.NC, Mechanical Problem Solving (no choice condition); RTU.C, Real Tool Use (choice condition); RTU.NC, Real Tool Use (no choice condition); SD, Semantic dementia (as a group); STU, Single Tool Use.

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pattern, that is, MPS deficits without semantic loss. However, additional qualitative research is needed to disentangle the relative contributions of motor and technical reasoning deficits to this pattern. Both of these profiles were found in patients with AD. For all that, these patients did not commit the same errors as stroke patients with left brain-damage documented in previous works. Several hypotheses are proposed to account for the specificity of tool use disorders in neurodegenerative diseases, and recommendations are provided to caregivers.

1. Introduction

1.1. *Aims of the present study*

It is known that difficulties in using everyday tools and objects are a core manifestation of apraxia (Baumard, Osiurak, Lesourd, & Le Gall, 2014; Bieńkiewicz, Brandi, Goldenberg, Hughes, & Hermsdörfer, 2014; Goldenberg, 2009; Heilman, Maher, Greenwald, & Rothi, 1997). It is also well-known that patients with dementia have difficulties in performing usual activities as well as in solving complex or novel problems (McKhann et al., 2011). Nevertheless, only very few studies have investigated tool use abilities in neurodegenerative diseases (see for example Lesourd et al., 2013), perhaps because the cognitive processes underlying tool use are still under debate (Buxbaum, Shapiro, & Coslett, 2015; Osiurak & Badets, 2016; Osiurak, Jarry, & Le Gall, 2010, 2011; Osiurak & Le Gall, 2014). In view of recent models of apraxia, normal tool use may depend on two complementary mechanisms, that is, semantic knowledge about tool function and context of use (Osiurak, 2014; Rothi, Ochipa, & Heilman, 1991, 1997; Roy, 1996; Roy & Square, 1985), and technical reasoning about physical properties of tools and objects (Osiurak et al., 2010, 2011; Reynaud, Lesourd, Navarro, & Osiurak, 2016; for a similar view, see; Goldenberg & Hagmann, 1998). In light of these hypotheses, the aim of the present study was to describe tool use disorders in dementia through a differential approach, in Alzheimer's disease (AD), semantic dementia (SD) and corticobasal syndrome (CBS).

1.2. *Theoretical background*

1.2.1. *Dementia subtypes*

Dementia is defined as a progressive decline of memory, reasoning, judgment, visuospatial skills, language and/or social behavior, interfering with usual activities and hence reducing autonomy (McKhann et al., 2011). Logically, tool use disorders should be observed in all-cause dementia but the underlying cognitive impairments are likely to be etiology-specific since the pattern of brain atrophy and the expected neuropsychological profile vary according to diagnosis. SD is associated with circumscribed atrophy of the ventral temporal lobes. It is characterized by a loss of knowledge observed in language (i.e., fluent but empty speech, loss of word meaning, semantic paraphasias) and/or perception (i.e., prosopagnosia, impaired recognition of objects identity or function) contrasting with normal language processing (i.e., repetition, reading) and perception (i.e., perceptual matching, picture reproduction; Gorno-Tempini et al., 2011; Neary et al., 1998). Corticobasal degeneration is characterized by brain atrophy in the basal ganglia and in frontal and parietal brain regions. It is associated with asymmetric limb rigidity, akinesia, dystonia and/or myoclonus, as well as with orobuccal or limb apraxia (i.e., ideomotor and/or limb-kinetic apraxia), cortical sensory deficit and/or alien limb phenomenon, but additional cognitive impairments are exclusion criteria (Armstrong et al., 2013; Litvan et al., 1997). The clinical diagnosis of AD requires either episodic memory disorders (i.e., amnestic presentation) or language, visuospatial or executive dysfunction (i.e., non-amnestic presentation; McKhann et al., 2011). Lesions are typically observed in the hippocampal region but they may also extend to frontal and parietal lobes.

According to Félician, Ceccaldi, Didic, Thinus-Blanc and Poncet (2003), cortical neurodegenerative diseases are well-suited models for testing cognitive-based hypotheses, for three reasons. First, lesions are relatively circumscribed at early stages of the disease. Second, in most cases the progression of cognitive impairments is stereotyped and sequential. Third, slowly progressive diseases may result in more stable functional reorganization than non-progressive lesions. Thus, it is appropriate to search for dissociations between semantic loss and problem solving deficits in neurodegenerative diseases.

1.2.2. *The semantic memory hypothesis*

According to cognitive models of apraxia Rothi et al., 1991, 1997; Roy, 1996; Roy & Square, 1985), tool use depends on explicit semantic knowledge about tool-object usual relationships (e.g., a hammer goes with a nail) and tool function (e.g., a hammer and a mallet share the same purpose). Notice that we shall use the terms “tool” and “object” to refer to the implement performing the action (e.g., screwdriver) and the recipient of the action (e.g., screw), respectively. Likewise, semantic memory may inform individuals about where to find tools if not present in the visual field (e.g., knowing that a hammer can be found in a workshop; see Osiurak, 2014; Osiurak et al., 2010). Loss of this type of knowledge causes conceptual apraxia, which prevents patients from either selecting relevant tools among distractors in multiple object tasks (Ochipa, Rothi, & Heilman, 1992), choosing among several pictures the one that shares common features with a target picture (i.e., functional association) or performing tool-related gestures in the absence of objects, as in single tool use