Brain & Language 155–156 (2016) 1–11

Contents lists available at ScienceDirect

Brain & Language

journal homepage: www.elsevier.com/locate/b&l

Regularity and beyond: Impaired production and comprehension of inflectional morphology in semantic dementia

Noémie Auclair-Ouellet [a,b,c,1], Joël Macoir [a,b], Robert Laforce Jr. [d], Nathalie Bier [e], Marion Fossard [c,*]

[a] Faculté de médecine, Université Laval, 1050, avenue de la Médecine, Québec, Québec G1V 0A6, Canada
[b] Centre de recherche de l'Institut universitaire en santé mentale de Québec, Axe des Neurosciences cliniques et cognitives, 2601, de la Canardière, Québec, Québec G1J 2G3, Canada
[c] Institut des sciences du langage et de la communication, Faculté des Lettres et Sciences humaines, Université de Neuchâtel, Rue de la Pierre à Mazel, 7, CH-2000 Neuchâtel, Switzerland
[d] Clinique interdisciplinaire de mémoire, Centre hospitalier universitaire de Québec, 1401, 18e Rue, Québec, Québec G1J 1Z4, Canada
[e] Centre de recherche de l'Institut universitaire de gériatrie, 4565, Chemin Queen-Mary, Montréal, Québec H3W 1W5, Canada

ARTICLE INFO

Article history:
Received 9 October 2015
Revised 28 January 2016
Accepted 26 February 2016
Available online 17 March 2016

Keywords:
Inflectional morphology
Semantic dementia
Production
Comprehension

ABSTRACT

Studies on inflectional morphology in semantic dementia (SD) have focused on the contrast between the regular and the irregular English past-tense. These studies aimed to contrast the claims of single- and dual-mechanism theories. However, both theories can account for impaired production of irregular verbs observed in SD. According to the dual-mechanism theory, this impairment is related to word-retrieval difficulties, while according to single-mechanism theory it is the consequence of semantic impairment. However, authors suggest that it is time to envision a broader role for semantic memory in the production of semantically encoded aspects of inflectional morphology. This study reports the performance of 10 French-speaking patients with SD in three tasks of inflectional morphology. Their performances were compared to those of a group of 20 age-, gender- and education-matched adults without cognitive impairment. Results show that SD patients had difficulties producing tense and person inflection in verbs and pseudo-verbs, whether regular or pseudo-regular. In a second task in which participants were directly exposed to regularity manipulations, SD patients tended to choose a more typical or predictable alternative over a correctly inflected verb. Results of the third task show that their difficulties in producing semantically encoded aspects of inflection, such as tense, are related to difficulties to understand the semantic content conveyed by inflectional morphemes. Overall, these results support the claim that semantic impairment can cause morphological deficits that do not only affect irregular verbs, but that also have impacts on the production and comprehension of semantic information conveyed by inflectional morphemes.

1. Introduction

Semantic dementia (SD) (also known as the semantic variant of primary progressive aphasia (svPPA) (Gorno-Tempini et al., 2011) is characterised by a central impairment of semantic cognition caused by anterior temporal lobe (ATL) atrophy (Lambon Ralph, 2014; Neary et al., 1998; Patterson, Nestor, & Rodgers, 2007). This semantic impairment is multi-modal and affects all aspects of cognition, whether verbal (e.g., word-finding, reading, etc.) or non-verbal (e.g., object drawing, object use, etc.) (Lambon Ralph, 2014). Over the years, studies have shown that this central impairment has several consequences, including difficulties in language domains that are not traditionally considered to rely heavily on semantic cognition, such as inflectional morphology (Benedet, Patterson, Gomez-Pastor, & Garcia de la Rocha, 2006; Cortese, Balota, Sergent-Marshall, Buckner, & Gold, 2006; Jefferies, Rogers, Hopper, & Lambon Ralph, 2010; Lambon Ralph et al., 2011; Meteyard & Patterson, 2009; Meteyard, Quain, & Patterson, 2014; Murray, Koenig, Antani, McCawley, & Grossman, 2007; Patterson, Lambon Ralph, Hodges, & McClelland, 2001; Patterson et al., 2006; Rochon, Kavé, Cupit, Jokel, & Winocur, 2004; Sajjadi, Patterson, Tomek, & Nestor, 2012; Wilson et al., 2014; for a review, see Auclair-Ouellet, 2015). Support for the presence of morphological difficulties in SD comes in large part from studies that target the production of inflected verbs in controlled contexts (i.e., carrier

* Corresponding author.
E-mail addresses: noemie.auclair-ouellet.1@ulaval.ca, noemie.auclairouelle@ucalgary.ca (N. Auclair-Ouellet), joel.macoir@rea.ulaval.ca (J. Macoir), robert.laforce@fmed.ulaval.ca (R. Laforce Jr.), nathalie.bier@umontreal.ca (N. Bier), marion.fossard@unine.ch (M. Fossard).
[1] Present address: Hotchkiss Brain Institute, Cumming School of Medicine, University of Calgary, Calgary, Canada.

http://dx.doi.org/10.1016/j.bandl.2016.02.002
0093-934X/

phrases) (Benedet et al., 2006; Cortese et al., 2006; Jefferies et al., 2010; Patterson et al., 2001, 2006; Wilson et al., 2014). In these contexts, the performance of SD patients is characterised by difficulties to produce the past-tense of irregular verbs, especially those of low frequency, while the production of regular inflected verbs is largely preserved (Jefferies et al., 2010; Patterson et al., 2001, 2006; Wilson et al., 2014). A rTMS study with young participants without cognitive impairment also supported the involvement of ATL in irregular verb inflection (Holland & Lambon Ralph, 2010).

Several studies focusing on the production of the English past-tense were motivated by a debate opposing the dual-mechanism (e.g., Ullman, 2001; Ullman et al., 1997), to the single-mechanism theory (e.g., Joanisse & Seidenberg, 1999; McClelland & Patterson, 2002). According to the dual-mechanism theory (e.g., declarative/procedural model: Ullman, 2001; Ullman et al., 1997), regular and irregular verb inflection are subtended by two completely independent mechanisms: the past-tense form of regular verbs is *generated* by a rule (subtended by procedural memory) while irregular verbs are *retrieved* in the lexicon. According to this theoretical proposition, patients that present lexical/semantic impairment are expected to have irregular verb-retrieval difficulties (Ullman, 2001; Ullman et al., 1997). The single-mechanism theory (e.g., connectionist models such as Parallel Distributed Processing (PDP) Joanisse & Seidenberg, 1999; McClelland & Patterson, 2002), rather suggest that all words and morphemes are represented by distributed patterns of activation over phonological, orthographic and semantic units. Since the past-tense form of irregular verbs is less similar to other forms of the same verb and does not follow the most frequent and predictable pattern of inflection (adding "–ed"), irregular inflected verbs' representations depend more on semantic units. Therefore, irregular verbs, especially those of low frequency, are more vulnerable to semantic impairment.

In the case of SD, both theories can account for the presence of specific difficulties in producing the past-tense of irregular verbs, and most importantly, no specific result or aspect of the participants' performance can rule-out the claims made by either one of the theories (Patterson & Holland, 2014). In fact, it is difficult to imagine an experimental manipulation that would determine that morphological processing is based on rules or on probabilistic connections (McClelland & Patterson, 2002; Patterson & Holland, 2014). Moreover, the interpretation that difficulties with irregular, low-frequency verbs often reported in SD are truly morphological in nature is controversial. In the dual-mechanism account, difficulties with these verbs can be explained by lexical retrieval impairment rather than morphological processing deficits (Kavé, Heinik, & Biran, 2012). Also, because semantics and grammar are traditionally considered as two independent and non-interacting aspects of language, some authors have claimed that irregular verb inflection deficits in SD could not be attributed to semantic impairment caused by ATL atrophy. According to these authors, morphological deficits would rather be related to additional language impairments caused by the progressive atrophy of neighbouring language regions of the brain (Bright, Moss, Stamatakis, & Tyler, 2008; Tyler et al., 2004).

It appears that by focusing on regularity, studies of morphology in SD have narrowed their scope on a very specific aspect of morphological processing and might have overlooked other aspects (Bishop, Nation, & Patterson, 2014). In fact, these studies and the theories on which they are based have not addressed how morphology is used to translate semantic information from the broader context into a conventional and synthetic way, i.e. inflectional morphology. This aspect of morphology, however, is more fundamentally semantic and is therefore susceptible to impairment in the case of central semantic impairment caused by ATL atrophy. Studies on aphasia of vascular origin bring interesting insight regarding this matter.

Following dual-mechanism perspectives of inflectional morphology and the tradition of aphasiology, patients with agrammatism in Broca's aphasia are expected to show larger impairments in the production of regular compared to irregular inflected verbs (Faroqi-Shah, 2007). According to this view, regular verbs are generated by the concatenation of a root and an affix at the stage of phonological encoding (Levelt, 1989). The fact that regular verbs are produced by assembling two elements instead of retrieving only one (as is the case for irregular verbs) makes them more complex, and hence more vulnerable to difficulties at the stage of phonological encoding, which is considered as the locus of morphological difficulties in Broca's aphasia (Levelt, 1989). However, it seems that dissociations of performance in agrammatism are the exception rather than the rule. A meta-analysis (Faroqi-Shah, 2007) found that half of the data sets analysed did not report dissociation in performance between regular and irregular verbs and that some studies even reported the opposite pattern of dissociation (larger impairment for irregular verbs compared with regular verbs).

Faroqi-Shah and Thompson (2003, 2004, 2007) proposed a hypothesis that could account for impairments found in both regular and irregular verb inflection in aphasia. According to the Diacritical Encoding and Retrieval hypothesis (DER), inflectional difficulties find their origin at the stage of diacritical features, which can be defined as parameters (such as tense and number) that must be specified in order to select the correctly inflected form of a verb. The authors suggest that diacritical feature impairments could take two forms: (1) difficulties in the activation of diacritical features based on the information provided by the context (e.g., time cues given by adverbs such as Yesterday, Tomorrow) and, (2) difficulties to retrieve the correct form of the verb based on diacritical feature activation. The first type of difficulties proposed by Faroqi-Shah and Thompson suggests an involvement of semantic (conceptual) nature in morphological impairments. For example, difficulties in semantic time processing could have impacts on the production of tense inflection in verbs. According to Faroqi-Shah and Thompson, the morphological difficulties of patients with agrammatism would be caused by impaired retrieval of an inflected form based on diacritical feature activation, the activation (or encoding) of diacritical features itself being well preserved. However, the two different forms of impairments found at the diacritical feature stage remain difficult to tease apart in practice, and since diacritical features are *syntactic* properties of the lemma (the lexical representation of a word) (Levelt, 1989), the question of how semantic/conceptual information is translated into diacritical features remains unclear.

Results suggesting that semantics would play a role in morphology were also found in studies on paragrammatism. Paragrammatism is an ensemble of language difficulties found in aphasia and characterised by impairments of syntax and morphology in an otherwise fluent language profile (Bastiaanse, 2011; Butterworth & Howard, 1987; Edwards, 2005). It has been far less studied than its pendant in non-fluent language profiles, agrammatism, yet several hypotheses were put forward to explain the origin of difficulties found in this language profile: lexical retrieval difficulties, syntactic and/or grammatical problems, or semantic/syntactic integration problems (Bastiaanse, 2011; Butterworth & Howard, 1987; Edwards, 2005). A recent study by Bastiaanse (2011) showed that in spontaneous language production, patients with paragrammatism produced as many verbs as normal control subjects and that the verbs they produced had normal diversity (as measured