Modeling aphasic sentence comprehension in a cue-based retrieval architecture

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Sentence processing deficits in aphasia become evident whenever patients have to rely on syntactic structure in order to derive the correct sentence interpretation. Aphasics are known to have difficulty in comprehending reversible non-canonical word order sentences compared to canonical word order (cf. Mitchum & Berndt, 2008). Representational accounts (e.g. Grodzinsky, 1995) assume that this difficulty with noncanonical sentences reflects disturbances in underlying syntactic representations. In contrast, according to processing accounts structural representations are unimpaired, but sentence comprehension is affected by a processing deficit, which leads to slowed processing or intermittent breakdowns of the parser (cf. Thompson & Choy, 2009). Studies investigating aphasic online sentence processing in addition to tradional off-line performance measures (e.g. Caplan et al., 2007; Dickey et al., 2007; Hanne et al., 2010) provide new evidence towards structurally unimpaired but delayed syntactic processing in aphasia.

However, in order to gain a better insight into patients' deficits, it is instructive to examine aphasic sentence comprehension within a computational architecture designed for modeling unimpaired processing. Existing computational models of aphasic syntactic processing (e.g. Haarmann et al., 1997; Crescentini & Stocco, 2005) are limited to modeling only offline measures. We employ the cue-based retrieval architecture (Lewis & Vasishth, 2005) which has already been shown to account for several key sentence comprehension phenomena in healthy individuals. The model, grounded in ACT-R (Anderson et al. 2004), consists of declarative and procedural memory where parsing unfolds through a series of memory retrievals guided by the application of production rules. The goal of this paper is to model offline as well as online sentence processing in aphasics suffering from sentence comprehension disorders, with minimal changes to the existing model.

As a test set we used eye movement data from a visual-world paradigm study in Hanne et al. (2010). The data consists of the eye movement patterns of controls (n=8) and individuals with aphasia (IWA) (n=7) during a sentence-picture matching task for German reversible canonical and non-canonical sentences (see (1a–b)).

We modeled eye movements as well as accuracy and reaction time data. We introduced a linking hypothesis based on retrievals in order to model visual-world paradigm data. Data from controls was modeled without modifying the existing parameter values. For modeling IWA data, we assumed: (i) No impairment in grammatical knowledge: IWA rely on the same grammatical representations as controls, (ii) Slowed Processing: Production rules in procedural memory are executed slower, (iii) Intermittent Deficiencies: Additional noise in the declarative memory representations.

The results of the simulations revealed qualitatively similar patterns for eye movements as well as accuracy and reaction time data for both- controls and IWA. We conclude: (i) aphasic sentence comprehension for reversible sentences can be modelled without assuming impairments in grammatical representations, (ii) both assumptions — slowed processing and noisy representations — are necessary to achieve a good model fit, (iii) the existing sentence processing model can explain offline as well as online data from

aphasic sentence processing, with minimal changes to the existing architecture.

(1) a. Canonical:
Der Sohn fängt den Vater
the_{NOM} son is_catching the_{ACC} father
'The son is catching the father'

b. Non-canonical:
Den Sohn fängt der Vater
the_{ACC} son is_catching the_{NOM} father
'The father is catching the son'

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