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The influence of sense-contingent argument structure frequencies on ambiguity resolution in aphasia

Anneline Huck[a,*], Robin L. Thompson[b], Madeline Cruice[a], Jane Marshall[a]

[a] Division of Language and Communication Science, School of Health Sciences, City, University of London, Northampton Square, London EC1V 0HB, UK
[b] School of Psychology, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK

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ABSTRACT

Verbs with multiple senses can show varying argument structure frequencies, depending on the underlying sense. When *acknowledge* is used to mean 'recognise', it takes a direct object (DO), but when it is used to mean 'admit' it prefers a sentence complement (SC). The purpose of this study was to investigate whether people with aphasia (PWA) can exploit such meaning-structure probabilities during the reading of temporarily ambiguous sentences, as demonstrated for neurologically healthy individuals (NHI) in a self-paced reading study (Hare et al., 2003). Eleven people with mild or moderate aphasia and eleven neurologically healthy control participants read sentences while their eyes were tracked. Using adapted materials from the study by Hare et al. target sentences containing an SC structure (e.g. *He acknowledged (that) his friends would probably help him a lot*) were presented following a context prime that biased either a direct object (DO-bias) or sentence complement (SC-bias) reading of the verbs. Half of the stimuli sentences did not contain *that* so made the post verbal noun phrase (*his friends)* structurally ambiguous. Both groups of participants were influenced by structural ambiguity as well as by the context bias, indicating that PWA can, like NHI, use their knowledge of a verb's sense-based argument structure frequency during online sentence reading. However, the individuals with aphasia showed delayed reading patterns and some individual differences in their sensitivity to context and ambiguity cues. These differences compared to the NHI may contribute to difficulties in sentence comprehension in aphasia.

1. Introduction

Language processing by neurologically healthy individuals (NHI) involves the integration of a variety of information sources at different levels, sometimes referred to as cues (Elman et al., 2005; MacDonald et al., 1994; MacWhinney and Bates, 1989; Spivey-Knowlton and Sedivy, 1995). These cues are integrated in an incremental manner, meaning that each word enters the processing system as soon as it is encountered, and is analysed in light of the information that is available at that point in the sentence (Marslen-Wilson, 1975). Further, it is assumed that processing is not just based on the information encountered, but that processing may additionally be based on predictions, expectations, and anticipations (Altmann and Kamide, 1999; Hare et al., 2009, 2003; Kamide, 2008; Kamide et al., 2003; Levy, 2008). Expectations can be based on probabilistic factors such as word frequency or the influence of a sentence context, which help to determine the statistical likelihood that a word or a structure occurs in a sentence. Eye tracking while reading studies demonstrated, for example, that fixation durations are shorter on predictable words than unpredictable words, and words that are predictable in context are more likely to be skipped than words that are unpredictable in context (Calvo and Meseguer, 2002; Kennedy et al., 2013; Kliegl et al., 2004; Rayner et al., 2011, 2004). One well-studied probabilistic factor is the frequency of a verb in a given argument structure, resulting in a verb's lexical bias. There is substantial evidence from studies in the healthy population that readers employ knowledge of a verb's lexical bias during syntactic parsing so that parsing is advantaged if a sentence structure is in accordance with the lexical bias of the verb occurring in that sentence (Garnsey et al., 1997; Trueswell et al., 1993). Hare et al. (2003) further revealed that one possible source of the probabilistic nature between a verb and its argument structure can be the relation between verb sense and structure, which again can be described probabilistically. Some polysemous verbs have different argument structure probabilities that vary depending on verb sense, and reading by NHI has been shown to be sensitive to these form-meaning correlations (Hare et al., 2003).

For many people with aphasia (PWA), the process of sentence comprehension is slow and effortful, and much less efficient than in

* Corresponding author.
E-mail address: Anneline.Huck.1@city.ac.uk (A. Huck).

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healthy processing. Sentence comprehension impairments in aphasia can present themselves through difficulties in comprehending non-canonical as compared to canonical sentence structures (Caramazza and Zurif, 1976; Grodzinsky, 2000; Hanne et al., 2011), or more generally, through poorer performance on complex compared to simple sentence types (Caplan et al., 2007, 1985; Knilans and DeDe, 2015; Thompson and Choy, 2009). While sentence processing impairments have traditionally been associated with Broca's aphasia and agrammatism (Caplan et al., 2007; Dickey et al., 2007; Friedmann and Shapiro, 2003; Thompson and Choy, 2009), there is evidence that they can also occur in other types of aphasia (Caplan et al., 1985; Dronkers et al., 2004). Results from an eye-tracking study investigating the reading of object and subject cleft sentences, for example, show similar reading patterns and similar reductions in sentence comprehension between participants with agrammatism and those with anomia (Knilans and DeDe, 2015).

There is evidence that the difficulty experienced by people with aphasia when they attempt to comprehend particular sentences is not limited to purely linguistic factors such as syntactic complexity, but is additionally defined by probabilistic factors that are based on language experience (DeDe, 2013a; Gahl, 2002; Gibson et al., 2016; Menn and Bastiaanse, 2016). More traditionally, these aspects have been described as 'heuristics' as opposed to 'linguistic' or 'algorithmic' (Gahl and Menn, 2016; Menn and Bastiaanse, 2016), and hence may not have received as much attention as they have in the study of sentence processing in the non-brain-damaged population. However, it has recently been emphasised that influences from probabilistic, i.e. experience-based predictions of upcoming linguistic information may contribute substantially to language processing in aphasia (Menn and Bastiaanse, 2016), and that usage-based approaches are important in the study of language in aphasia as they may be able to explain why language difficulties are often variable (Gahl and Menn, 2016). This variability may be due to the varying probability of a sentence, making sentences of high probability easier to understand than sentences of low probability (Gahl and Menn, 2016). According to the *Lexical Bias Hypothesis*, PWA are, like NHI, sensitive to lexical biases in sentence comprehension, and lexical biases can at least account for some difficulties in comprehension (Gahl, 2002). More specifically, PWA may show an advantage in processing sentence structures that match the lexical biases of the words compared to sentence structures that conflict with the argument structure frequency of words in the sentence (DeDe, 2013a, 2013b, 2012, 2008; Gahl, 2002, 2000; Gahl et al., 2003). However, there is no evidence as to whether individuals with aphasia can employ more fine-grained probabilistic factors such as argument structure frequencies that are based on verb sense, and whether sentences that conflict with sense-contingent argument structure probabilities impose difficulties on sentence reading. The purpose of this paper is to investigate whether people with aphasia are able to use sense-based argument structure frequencies when they read sentences containing a structural ambiguity. We use the analysis of eye movements which has recently been shown to be a successful method to analyse reading by people with aphasia (Chesneau et al., 2007; Kim and Bolger, 2012; Knilans and DeDe, 2015). If meaning-structure correlations are resilient to breakdown, they may be used by people with aphasia. It might be that processing difficulty in aphasia is, amongst other factors, dependent on the strength of probabilistic relations within the language system.

The influence of multiple sources of information or cues on sentence comprehension is mainly studied within the constraint-based approach, a parallel and interactive model of sentence processing (MacDonald et al., 1994; MacWhinney and Bates, 1989; McRae et al., 1998; Seidenberg and MacDonald, 1999; Spivey-Knowlton and Sedivy, 1995; Trueswell, 1996; Trueswell et al., 1993). Constraint-based theories emphasize the influence of statistical regularities on language processing. Next to argument structure frequency as discussed above, different information sources such as lexical, semantic or pragmatic knowledge, context, world knowledge or thematic fit, discourse, prosody or animacy (Altmann and Steedman, 1988; DeDe, 2010; Garnsey et al., 1997; McRae et al., 1998; Spivey-Knowlton and Sedivy, 1995; Trueswell et al., 1994) can determine the probability of a word or structure in a sentence, and can hence act as probabilistic constraints on sentence comprehension. Information sources are referred to as 'cues' or 'constraints' as these sources are cueing or constraining the structural interpretation of the (ambiguous) sentence.

The remainder of this introduction will provide a summary on the influence of argument structure frequencies on the processing of structural ambiguities in populations without brain damage as well as in aphasia. Further, recent studies of predictive processes in aphasia will be described in more detail before we provide an overview of studies using eye tracking to study sentence processing in aphasia. The introduction ends with a more detailed presentation of the aims and predictions of this study.

1.1. The influence of argument structure frequency on the processing of sentences containing a temporary ambiguity in the non-brain damaged population

Investigations of argument structure frequencies or other types of probabilistic cues on the influence of sentence comprehension by NHI have often used the paradigm of structural ambiguity (Ferreira and Henderson, 1990; Hare et al., 2003; Traxler and Tooley, 2007; Trueswell et al., 1993); a paradigm that has recently also sparked interest in aphasia (DeDe, 2013b, 2012). Structurally ambiguous sentences, sometimes termed 'garden path' sentences, contain a region that could be part of two different syntactic structures. Studying how readers process such a region can reveal the influence of different sentence cues. For an example, see sentences (1) and (2), which illustrate the direct object/sentential clause ambiguity:

(1) The teacher **remembered** (that) *the book* was locked inside the desk
Sentence complement (SC)
(2) The teacher **remembered** *the book* and walked back
Direct object frame (DO)

Here, the noun phrase *the book* is temporarily ambiguous when the complementiser *that* is omitted. *The book* could be the direct object (DO) of *remember* as in (2) or the subject of a new sentence complement clause (SC) as in (1). It is only at the disambiguation area *was locked inside the desk* that the structure unfolds fully. A number of studies have investigated the influence of argument structure frequency (verb bias) on the processing of the DO/SC ambiguity, and revealed that NHI show an ambiguity effect (a misanalysis) in the disambiguation region for those verbs that are biased to occur with a direct object but not for verbs that are biased to occur with a sentence complement (Garnsey et al., 1997; Trueswell et al., 1993). The paradigm of structural ambiguity allows the manipulation of sentences to study how different sources of information influence parsing decisions.

A more fine-grained type of information source that has been studied using the DO/SC ambiguity, is the influence of sense-contingent argument structure frequency (Hare et al., 2004, 2003). The lexical bias of polysemous verbs can vary according to which meaning is intended; the verb *find*, for example, prefers to occur with a DO if it is used in the sense of 'come upon after searching' or 'to locate', but it prefers a SC if it is used in the sense of 'to make a discovery' or 'to realise' in a mental sense. Hare and colleagues carried out a self-paced reading study in which they analysed the influence of sense-contingent argument structure frequencies on the resolution of sentences with a structural ambiguity. For an example, consider (3) and (4) below:

(3) DO biasing context (sense: LOCATED)

(i) Allison and her friends had been searching for John Grisham's new novel for a week, but yesterday they were finally successful.