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

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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.

Keywords: Aphasia; Structural Ambiguity; Garden-Path; Argument Structure Frequency; Probabilistic Cues; Verb Sense; Eye Tracking

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 also 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 and colleagues (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 healthy processing. Sentence comprehension impairments in aphasia can present themselves through difficulties in comprehending non-canonical as compared to canonical sentence structures following subject, verb, object word order (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.
- (ii) They **found** (that) <u>the book</u> was written poorly and were annoyed that they had spent so much time trying to get it.

(4) SC biasing context (sense: REALISED):

- (i) The intro psychology students hated having to read the assigned text because it was so boring.
- (ii) They **found** (that) <u>the book</u> was written poorly and difficult to understand.

Target structures (ii) were sentence complement structures and were either ambiguous (omitting *that*) or non-ambiguous (including *that*). Context sentences (i) were constructed to create a semantic scenario, intended to create an expectation of either the REALISED sense of find in (4), or the LOCATED sense of *find* as in (3). The goal of the context sentences was to prime either the DO-based argument structure frequency (3) or the SC-based argument structure frequency (4), and accordingly, their associated structures. Results from this study showed that the NHI had the longest reading durations in the disambiguation region (*written*) when the context biased them for the incorrect DO-sense and associated structure, particularly when the sentence was ambiguous. Hence, structural expectations were shown to be contingent on verb sense - promoted by context.

In conclusion, studies carried out with the non-brain damaged population suggest that sense-independent argument structure frequency as well as sense-contingent argument structure frequency are two types of probabilistic cues that may influence how NHI process sentences with a temporary structural ambiguity.

1.2 The influence of argument structure frequency on the processing of sentences containing a temporary ambiguity in aphasia

A number of studies adopted the constraint-based approach to investigate whether sentence comprehension in aphasia is influenced by lexical biases (for a review of probabilistic sentence processing in aphasia (usage-based approaches) see Gahl & Menn, 2016). Studies that focused on the comprehension of structurally simple sentences investigated the transitivity bias, i.e. the likelihood that a verb occurs in either a transitive or intransitive structure. With the exception of the study by Russo et al (1998), an effect of lexical bias was found, although not for all types of aphasia (DeDe, 2013a; Gahl, 2002; Gahl et al., 2003). These results are consistent with findings from the non-brain damaged population, and support the Lexical Bias Hypothesis.

Some more recent studies focussed on sentences with a structural ambiguity, one using self-paced listening and one using self-paced reading[1] (DeDe, 2013b, 2012). These studies allow an investigation of what type of information sources guide sentence comprehension in aphasia, when they are available, and how they interact (DeDe, 2010). Both of the studies suggest that PWA can employ argument structure frequencies when they process temporarily ambiguous and non-ambiguous sentences. Interestingly though, they also evidenced differences in comparison to the NHI. In a self-paced listening study, DeDe investigated verb bias (conflated with plausibility) as well as prosody cues on the comprehension of early closure ambiguities[2] (DeDe, 2012). Results suggested that the PWA were delayed in the time course of processing the lexical bias, as evidenced by an effect of lexical bias that occurred in a later sentence region as compared to the NHI. Further, the PWA had difficulties processing the sentences when the cues were at conflict with each other, e.g. when verb bias and plausibility cued for one structure but prosody for the other.

In a self-paced reading study, DeDe (2013a) examined the influence of argument structure frequency and the presence/absence of the complementiser *that* on the DO/SC ambiguity that was introduced in 1.1. Whilst the NHI relied more on the presence/absence of the complementiser *that*, PWA relied more on the verb bias. If the PWA were delayed in processing closed-class words such as the complementiser *that*, it is tenable that they relied on the cue that is more reliable for them which is verb bias (DeDe, 2013a). This result may suggest that the verb bias reflected a compensatory mechanism, i.e. focussing on the cue that is more available. In addition, the PWA showed the effect of ambiguity in a later region than the NHI, as

[1] In the self-paced listening and the self-paced reading paradigm, sentences are divided into segments. The participants listen to or read these segments at their own speed, pressing a button when they finish one segment and would like to proceed to the following one. Listening and reading times are analysed for segments of the sentence, and these are interpreted as reflecting processing demand.

[2] In early closure sentences (e.g. *While the parents watch (,) the child sings a song with her grandmother*), the second noun phrase (*the child*) is the beginning of a new clause. However, the second noun phrase contains a temporal ambiguity, because it could also be the object of the subordinate verb as in late closure sentences (e.g. *While the parents watch the child (,) she sings a song with her grandmother*).

evidence for delayed processing of the cue, and hence consistent with findings from the listening study.

To sum up, research suggests that PWA are influenced by argument structure frequency when they process structural ambiguities. However, there is no evidence regarding whether PWA can employ more fine-grained probabilistic cues such as sense-contingent argument structure frequencies, whether cues are always processed in a delayed fashion, and whether all PWA have difficulties integrating cues. It should be kept in mind that differences in the effect of cues are likely to vary individually, depending on the underlying language profile.

1.3 Prediction and expectation in aphasia

In some situations cues have to be processed quickly in order to be integrated with other information, and in order to lead to expectations in language processing. In the study by Hare and colleagues, for example, the context sentence has to be processed before the reader approaches the target verb so that the semantic scenario from the context can bias the intended verb sense and consequently lead to an expectation of the following sentence structure. Studies have shown that healthy people, mostly young adults, are able to make rapid predictions and anticipations during language processing (Altmann and Kamide, 1999; Hare et al., 2009, 2003; Kamide, 2008; Kamide et al., 2003; Levy, 2008). Evidence suggesting that people with aphasia can use predictions and expectations in language processing is less clear (Warren et al., 2016). Interestingly, some recent studies suggest that such processes may be intact, at least for some people with aphasia. Conducting a self-paced reading study, Dickey and colleagues demonstrate that people with aphasia show robust prediction in the comprehension of sentences, evidenced by predictability effects on critical words in constraining sentence contexts (Dickey et al., 2014). Two eye-tracking while reading studies further indicate that the role of a predictive context may be magnified in people with aphasia as compared to controls, as demonstrated by a larger effect of a constraining sentence context by the people with aphasia in comparison to the healthy readers (Huck et al., 2017; Kim and Bolger, 2012).

Further to results on lexical predictions, Mack et al conducted two visual-world paradigm studies that explored whether individuals with agrammatic aphasia can use verb meaning to predict or to facilitate the integration of an upcoming verb argument (Mack et al., 2013). In one experiment, the NHI and PWA listened to sentences including a restrictive/unrestrictive verb, but omitting the noun phrase argument (e.g. *Tomorrow Susan will open/break …)* while looking at an array of four pictures. The restrictive verb (e.g. *open*) was compatible with one picture, and the unrestrictive verb (e.g. *break*) was compatible with all four pictures. Both participant groups showed a gaze preference to the target picture in the restrictive condition. For the NHI this effect occurred immediately after hearing the verb, but it was delayed for the PWA, suggesting that people with agrammatic aphasia are impaired in forming timely predictions. Their second experiment, however, indicated that individuals with aphasia are able to use verb meaning to facilitate the integration of an upcoming verb argument.

Hanne et al demonstrated that the extent to whether PWA are able to form predictions of upcoming syntactic structure may be dependent on the properties of the cues under investigation (Hanne et al., 2015). Their eye-tracking-listening study demonstrated that PWA can predict syntactic structure in situations in which morphological cues are unambiguous but not if they are ambiguous (Hanne et al., 2015). The question of whether people with aphasia can engage in structural prediction was further explored by Warren and colleagues (Warren et al., 2016). They conducted a self-paced reading study, manipulating the presence of *either,* followed by disjoined noun phrases (e.g. *Emily painted (either) a lovely still life or a beautiful portrait of her mother*). Even though *either* can occur with a number of structures, it is a strong cue for an upcoming disjunction. Results revealed that PWA and control participants read the critical region *or* together with the second disjunct (e.g. *or a beautiful portrait*) faster when it was preceded by *either* than when not preceded by *either*. This suggests that they used the lexical cue to predict the upcoming sentence structure, which facilitated reading of this region.

Summing up, evidence towards predictive processing in aphasia is limited. Nevertheless, several studies demonstrate that predictive processing in aphasia may be preserved, at least when cues are strong and unambiguous; however, such processing may be slowed in comparison to control participants.

1.4 Using eye tracking to study sentence comprehension in aphasia

Eye tracking has several benefits for studying sentence comprehension in aphasia. Whereas offline (behavioural) measures such as accuracy are restricted to examining whether the task was successful or not, eye tracking allows for an investigation of sentence processing in real-time that is not influenced by meta-strategies and that is largely automatic. In aphasia research, eye tracking has been used to investigate listening comprehension, using the visual world paradigm (Bos et al., 2014; Dickey et al., 2007; Dickey and Thompson, 2009; Hanne et al., 2015, 2011; Laurinavichyute et al., 2014; Mack et al., 2013; Meyer et al., 2012; Schumacher et al., 2015; Sheppard et al., 2015; Thompson and Choy, 2009). In this paradigm, people listen to linguistic stimuli whilst they observe visual scenes that include elements from the linguistic input. Most notably, these studies revealed that complex sentences structures can be processed successfully at least some of the time (Choy and Thompson, 2010; Dickey et al., 2007; Dickey and Thompson, 2009; Hanne et al., 2011; Thompson and Choy, 2009), pointing to important residual competences in aphasia. When difficulties arise, they often occur towards later stages of processing, with findings that point to lexical processing impairments such as a delay in lexical processing or deficits in lexical integration, rather than syntactic impairments per se (Dickey et al., 2007; Hanne et al., 2011; Meyer et al., 2012).

Some studies used eye tracking to investigate reading at the word level (Ablinger et al., 2014; Huber et al., 1983; Klingelhöfer and Conrad, 1984; Schattka et al., 2010), but eye tracking has been used much less to investigate written sentence comprehension or the process of silent sentence reading. Kim and Bolger (2012) demonstrated that a semantic context facilitates reading by PWA, as evidenced by shorter reading times on words that are predictable from the sentence context than on words that are not predictable given the sentence context. Knilans and DeDe (2015) compared how PWA and NHI read object and subject cleft sentences, which differ in their structural frequency; subject relative sentences occur more frequently in English than object relative sentences (Roland et al., 2007), and hence create a bias or an expectation for this structure. Their eye movement data revealed that reading by both the PWA and the control group was sensitive to such structural frequencies.

1.5. Aims and predictions of this study

The present study investigates whether individuals with aphasia as well as individuals without brain damage use sense-contingent argument structure frequency during the on-line processing of the DO/SC ambiguity. Replicating the experimental design of Hare and colleagues (2003), target sentences, which all employ the SC structure, follow a context sentence that either biases the DO-interpretation of the target verb, or biases the SC-interpretation of the target verb. The goal of this design is to create a context sentence that promotes the sense-contingent argument structure of the target verb. Target sentences are either ambiguous (omitting the complementiser *that*) or non-ambiguous (including *that*).

The first aim of this study is to examine whether the context bias and the presence or absence of the complementiser *that* influence on-line reading for individuals with aphasia in comparison to individuals without brain damage. In line with previous research we expect that NHI would show an effect of the context bias (Hare et al., 2003) as would be reflected by longer fixation durations on the disambiguation region following the DO-bias than the SC-bias. Further, we expect an effect of ambiguity with longer fixation durations in the disambiguation region if the complementiser is omitted as compared to when it is included (Garnsey et al., 1997; Hare et al., 2003; Trueswell et al., 1993). More specifically, we predict that NHI show most sensitivity to the context bias if the sentences are ambiguous, meaning that they only exploit the context cue if the sentence is ambiguous, evident of successful integration of the two factors (Hare et al., 2003). We mainly expect effects to show in the disambiguation region, which is where the misanalysis becomes apparent.

Based on previous findings of general (sense-independent) argument structure frequency effects in aphasia (DeDe, 2013a; Gahl, 2002; Gahl et al., 2003), including an effect of verb bias on the reading of sentences including a temporal structural ambiguity (DeDe, 2013b, 2012), it is predicted that PWA show – equally to NHI – an effect of the context bias. Further, we expect that PWA can employ context cues, as sentence context has generally been found to facilitate sentence comprehension in aphasia (Germani and Pierce, 1992; Pierce, 1988; Pierce and Wagner, 1985). However, we also anticipate some differences between the two groups with respect to how the two cues can be accessed during sentence processing. In line with a previous study showing that verb bias is a stronger cue for PWA than the presence of a complementiser (DeDe, 2013b), we expect that the context bias effect should be larger as compared to the ambiguity effect for the PWA, but not for the NHI. We do, however, expect some effects of ambiguity on processing in the aphasia group as most participants with aphasia in this experiment only have a mild type of aphasia, which may delay access to a complementiser, but not necessarily forbid it.

It is also anticipated that the groups would diverge in the time course of processing. If people with aphasia were slow in lexical access and/or lexical integration as shown in eye tracking whilst listening studies (Dickey et al., 2007; Dickey and Thompson, 2009; Hanne et al., 2011; Meyer et al., 2012), we would expect that effects from the context and the ambiguity manipulation would be shown in a delayed fashion as compared to the NHI group. Slowed processing of cues has been shown in a study on the processing of structural ambiguities in aphasia before (DeDe, 2012), and also in a study investigating the use of verb meaning to predict an upcoming noun phrase (Mack et al., 2013). A delay could be evident by effects occurring in a later region in comparison to the control participants, that is, following the disambiguation region, or by effects in a later eye movement measurement (i.e. in total fixation duration) as compared to the control participants. These effects could be revealed in several of the analysed regions as PWA may re-read parts of the sentence to understand it correctly.

Our second aim is to find out whether the individuals with aphasia show any individual differences in terms of the context and ambiguity effects, and if so, whether these differences are associated with their specific underlying language impairment. Individual variation will be investigated with respect to aphasia severity, lexical-semantic processing, sentence comprehension skills, and working memory. A previous study on how neurologically healthy participants process the DO/SC ambiguity has shown that vocabulary knowledge predicted the magnitude of processing disruption when there was a mismatch between verb bias and target sentence structure, and further, that the ambiguity effect was less pronounced the better the working memory of the participants (Traxler and Tooley, 2007)[3].

If participants are not sensitive to the sense-bias but to the sense-independent verb bias, then they should show a tendency to expect a DO-structure. All verbs included in this experiment have an overall DO-bias, as established in an analysis using the British National Corpus (Wiechmann, 2008). This sense-independent verb bias conforms to a global transitivity bias in the English language, that is, a general preference for a verb to occur with a direct object (Bever, 1970). An effect of such should be demonstrated by shortest reading times in the noun phrase region for the ambiguous condition following a DO-bias. In this condition, both cues favour a transitive interpretation, and this is before the disambiguation region where the SC-structure becomes apparent. Table 1 presents an overview of the main predictions of this study.

Table 1. Summary of main predictions of this study

	Groups	
Predictions	**NHI**	**PWA**
Presence and magnitude of effects	Pronounced effects of ambiguity and context	Pronounced effects of context and reduced effects of ambiguity
Time course	Effects mainly shown in the disambiguation region	Effects shown later in comparison to NHI: in later regions (post disambiguation region) or later eye movement measurements (total fixation durations as compared to first fixation duration, gaze duration or first-pass regression)
Individual differences	Not under investigation	Differences based on aphasia severity, lexical-semantic processing, sentence comprehension skills, or working memory

2. Methods

2.1 Participants

[3] Note that in this study the focus was on how individual variation in vocabulary knowledge and working memory influences processing of the structural DO/SC ambiguity. Test sentences were constructed so that the ambiguity resolution was influenced by a combination of verb bias and semantic plausibility - which both favoured the misanalysis. The two factors were not investigated independently of each other.

Ethical approval was granted from the School of Health Sciences Research Ethics Committee, City, University of London. All NHI and PWA gave informed consent. Eleven people with aphasia due to a single left hemisphere stroke (8 women, mean age 55.55 (*SD* = 8.95), *range* = 41-71) and eleven neurologically healthy participants (5 women, mean age 51.82 (*SD* = 12.06), *range* = 36-71) took part in this study. The participants with aphasia were at least six months post-onset (*mean* = 7 years and 7 months). Demographic data of the participants with aphasia are provided in Table 2. Detailed language assessments are described in Section 2.1.1. The participants without neurological impairments had age-appropriate cognitive functioning as shown by a mean score of 29.73 (*SD* = 0.65, *range*: 28-30/30) in the Mini-Mental State Examination, 2nd Edition Standard Version (MMSE-2: SV) (Folstein et al., 2010). They reported no history of speech-language impairments or reading difficulties.

The groups were comparable with respect to both age and education (both $p \geq .27$). Participants from both groups were native speakers of English, were right-handed, and presented without evidence of visual (-spatial) impairments (e.g. glaucoma, visual field impairment, or visual neglect). The line bisection task from the Comprehensive Aphasia Test (Swinburn, Porter, & Howard, 2004) and a letter cancellation task (Weintraub & Mesulam, 1985) screened for visual impairment for the PWA. The letter cancellation screens visuo-spatial skills and can detect visual neglect (Ferber & Karnath, 2001; Hartje & Poeck, 2002). None of the participants made more than one error in this task, hence there was no indication of such visual impairments. The line bisection task investigates the ability to see size relation within an object, and has been shown to be sensitive to hemianopia (Ferber & Karnath, 2001; Hartje & Poeck, 2002). In this task, a line bisected in equal halves scores 0: negative values indicate a deviation to the left and positive values indicate a deviation to the right. Scores of three lines are added up to a total score ranging from 0 (no deviance) to -6/+6 (strong deviance). The maximum total score of a participant in this task was -2 (*range* = -2 - +1.25). If participants reported visual field impairments but were not in possession of the reports, or if there was any doubt about screening results, additional perimetry testing (visual field test) was carried out. Rare impairment are reported in reading when the parafoveal visual field sparing of 10° is not compromised (Schuett et al., 2008). Hence, 10° visual field sparing was used as the cut-off criterion. The perimetry testing took place within the Optometry Department of City, University of London, and was carried out by the first author on an Octopus Perimetry. This procedure screened out two potential participants. Participants from both groups had no history of developmental dyslexia and no cognitive impairment such as dementia (for the PWA this was based on self-report as the MMSE-2: SV is not designed to test participants with language impairments).

Table 2. Demographic information for participants with aphasia

ID	Gender	Age	Education (Group)[a]	Years. Months post Onset	Aetiology	Localisation
1	f	62	Master's (6)	14.6	Ischemic CVA	Left
2	f	50	No formal (1)	16	Ischemic CVA; subarachnoid hemorrhage	Left, MCA; PCOM aneurysm
3	f	52	Apprenticeship (3)	2.6	Ischemic CVA	Left parietal
4	f	65	GCSE (2)	1.11	Ischemic CVA	Left, MCA
5	m	47	Diploma (4)	9	Ischemic CVA; hemorrhagic CVA	Left frontal parietal
6	f	41	Apprenticeship (3)	5.1	CVA	Post central left parietal lobe
7	f	55	Bachelor's (5)	16.5	Ischemic CVA	Left, MCA
8	f	47	PhD (7)	2.5	Ischemic CVA	Left, MCA
9	m	71	Diploma (4)	8.3	CVA	Left
10	m	66	Bachelor's (5)	3.8	CVA	Left
11	f	55	Master's (6)	5.4	Ischemic CVA, hemorrhage	Left, insular
n.a.	n.a.	M = 55.55 (SD = 9.38)	M = 4.18 (SD = 1.83)	M = 7.74 (SD = 5.57)	n.a.	n.a.

[a]Education groups: (1) no formal, (2) GCSE, (3) A levels/Apprenticeship, (4) Diploma/College Degree, (5) Bachelor's Degree, (6) Master's Degree, (7) Doctoral Degree
CVA = cerebrovascular accident; MCA = middle cerebral artery

2.1.1 Language and cognitive assessments for PWA

Several language assessments were administered, and composite scores were calculated to gain scores of different aspects of language. The results from the background language assessments are presented in Tables A.1-A.3 (composite scores are represented in shaded cells). Type and severity of aphasia was assessed using the *Western Aphasia Battery - Revised* (WAB-R, Kertesz, 2007). Severity scores demonstrated that nine participants had mild aphasia (AQ > 76), and two had moderate aphasia (AQ = 51-75). Eight participants had Anomic aphasia, two had Conduction aphasia, and one participant had Broca's aphasia (see Table A.1). Two composite scores were calculated to measure lexical-semantic processing. A **lexical-semantics written comprehension score** was calculated to gain a score that includes written processing only. It comprises the average of the visual lexical decision task and the written word to picture matching test from the *Psycholinguistic Assessments of Language Processing in Aphasia* (PALPA, Kay, Lesser, & Coltheart, 1997). This showed good written word comprehension with an average of 95%, with the lowest score being 84% and the highest 100% (see Table A.2). A

lexical-semantics composite score represented the average of the lexical-semantics written comprehension composite score and the lexical production score (see Table A.2). The latter comprised the object (noun) naming task from the PALPA and the action (verb) naming task of the *Verb and Sentence Test* (VAST) (Bastiaanse, Edwards, & Rispens, 2002). The mean was 90% with a range of 81%–96% (see Table A.2). In addition to these word-level assessments, a **sentence comprehension composite score** was calculated representing the average of the sentence to picture matching test (PALPA), and the average of the canonical and non-canonical sentence comprehension score from the VAST. Participants had a mean of 85%, and the range was 70-96% (see Table A.3). Overall, comprehension accuracy was better in canonical sentences (M = 95%) as compared to non-canonical sentences (M = 71%) (Z = -2.94, p = .003). Six out of eleven participants had a discrepancy of ≥ 20% between canonical and non-canonical sentence types.

Working memory (WM) was assessed with the WM digit forward and backward span tasks from the Wechsler Memory Scale (Wechsler, 1997). None of the participants with aphasia had difficulties in verbally producing digits; hence the digit span task was judged to be appropriate. Additionally, a WM sentence span task was used that was developed for people with aphasia, and that used recognition instead of recall (Caspari et al., 1998). People with aphasia had a mean score of 5 for the WM digit forward span, 3.55 for the WM digit backward span (forward norm[4]: M = 5.98, SD = 1.12; backward: M = 4.30, SD = 1.11), and 4.36 for the WM sentence span (see Table A.3).

2.2 Materials

2.2.1 Selection of target verbs

Ten polysemous verbs were selected from the original study by Hare and colleagues (2003), which used 20 verbs[5]. These 20 verbs were identified as they had two distinct senses listed in WordNet (Miller et al., 1990), and allowed for a sentence complement (SC) and a direct object (DO) argument structure. In most cases, these distinct senses comprised a concrete and a more abstract sense (such as *find* meaning 'come upon after searching' in a concrete sense or meaning 'realise' or 'discover' in a mental sense). Sense keys are provided in Appendix C, Table C.1. Hare and colleagues carried out corpus analyses in order to calculate both sense-independent and sense-contingent argument structure frequencies for these verbs. While sense-independent

[4] Norms are from the manual of the Wechsler Memory Scale (Wechsler, 1997) and are based on a group of healthy participants (N = 46) within the age group of 40–49.
[5] The number of stimuli was reduced to make the experiment feasible for the participants with aphasia. We selected those ten verbs for which the constructed context sentences created the expected biases, as further detailed in the description of the norming studies below.

verb bias varied amongst corpora, the sense-contingent verb biases calculated from WordNet's Semantic Concordance demonstrated a probabilistic relationship between verb senses and their argument structures; verbs used in the concrete, or DO-biased sense, preferred a DO-structure and verbs that were used in the abstract, or SC-biased sense, preferred a SC-structure.[6]

In order to investigate whether people with aphasia can access such probabilistic relationships between the verb senses and their argument structures, a set of items was developed that analysed whether the interpretation of a certain verb sense influences the interpretation of the DO/SC ambiguity. Each verb was embedded into a target sentence that followed a sense-priming context sentence. The context sentence was created to bias readers for either the sense that is probabilistically associated with the DO-structure, or the sense that is associated with the SC-structure. The target sentence was either ambiguous between the DO/SC structure (no 'that'), or unambiguous (including 'that'). All target sentences occurred in the SC-structure. Context and target sentences were either taken from the original study, or were adapted to render them more suitable for a study involving people with aphasia. In many cases sentences were simplified by reducing the number of words in the sentence, both in the context and also in the target sentences. Further, infrequent words were substituted with more frequent words, and in some instances the sentence structure was simplified. Following Hare et al., context sentences included no SC-structures to avoid structural priming, and context sentences did not invoke strong expectations for the specific target verbs, but evoked a semantic scenario. Also, the contexts for the verbs never included any target verbs. The number of context sentences that contained the noun phrase from the target sentence (e.g. *his old friend*) was kept to a minimum, and was roughly equal across conditions, with three in the DO-bias condition and four in the SC-bias condition. Target sentences (for example: *After a while he **recognised** (that) <u>his old friend</u> had adopted a different look and appeared completely different.*) were constructed to include a personal pronoun (*he*), the target verb (*recognised*), the complementiser (*that*) in the non-ambiguous trials, the (ambiguous) noun phrase (*his old friend*), and continued with a sentence complement (*had adopted a different*…). In order to ensure that the noun phrase was not acting as a plausibility confound in this experiment, it was kept plausible as a direct object of the target verb as well as a subject of the sentence complement clause. The first two words following the noun phrase comprised the disambiguating region (*had adopted*), followed by a post-disambiguation region (*a different*) and a sentence ending (*look and appeared completely different/lifestyle and living together would not work out*). Except for two verbs, sentence endings differed in the two context conditions to render them semantically appropriate given

[6] It should be noted that this analysis could only be carried out for twelve of the twenty verbs as there were too few sense-specific example sentences in the WordNet Semantic Concordance for the other eight verbs.

the context bias. Up to the sentence ending and thus in the critical regions, target sentences were identical in both context conditions. For a more detailed description of the construction of context and target sentences see Hare et al. (2003). In summary, the material comprised four conditions: 1) DO-biasing context and ambiguous target sentence (omitting *that*); 2) DO-biasing context and non-ambiguous target sentence (including *that*); 3) SC-biasing context and ambiguous target sentence (omitting *that*); and 4) SC-biasing context and non-ambiguous target sentence (including *that*). Since each of the ten verbs appeared in four different conditions, there were 40 experimental target sentences following 40 context sentences. A set of conditions for the target verb *recognise* is shown in Table 3. A full set of stimuli sentences can be found in Appendix C.

Table 3.
Example sentences for the verb *recognise*

Context	Ambiguity	Example
DO-bias		When Billy went to the party he did not know any familiar faces.
	ambiguous	(1) After a while he **recognised** <u>his old friend</u> had adopted a different look and appeared completely different.
	unambiguous	(2) After a while he **recognised** that <u>his old friend</u> had adopted a different look and appeared completely different. Question: Did Billy think his friend looked different now?
SC-bias		Gordon had moved in with his old friend, but they argued a lot.
	ambiguous	(3) After a while he **recognised** <u>his old friend</u> had adopted a different lifestyle and living together would not work out.
	unambiguous	(4)After a while he **recognised** that <u>his old friend</u> had adopted a different lifestyle and living together would not work out. Question: Did Gordon think living with his friend was working well?

2.2.2 Norming studies

Following Hare et al. (2003), we conducted two norming studies to ensure that the probabilistic relationships between verb sense and argument structure that were identified in the corpus analysis were upheld for the linguistic stimuli. Both norming studies were conducted online and involved participants without brain damage (a different group to the one taking part in the eye tracking study). The goal of the first study was to establish whether the constructed context sentences activated the intended sense and associated structure of the verb. Participants (N = 70, mean age = 41.35, range = 18 – 76) were given the context sentence followed by the first fragment of the target sentence (e.g. *When Billy went to the party he did not know any familiar faces. After a while he recognised…*) and were asked to supply a sentence ending. Two lists were constructed and participants read each context and each verb only once; each subject saw half of the verbs following a DO-biasing context, and half following an SC-biasing context. Norming stimuli were interspersed with twelve filler items that varied in syntactic structure and that were truncated at different points. All sentences were randomised. The sentence completions were first coded for target verb sense (DO/SC/other) and subsequently, argument structure probabilities were calculated for those sentences that used the target verb sense (DO/SC/other)[7]. The sense of the verb was judged on the basis of the overall meaning of the sentence completion, and categorised based on the two senses as established in WordNet. Results (see Table 4) show that the contexts were successful in priming verb sense in that the DO-sense of the verb was mostly used following a DO-bias context (92.45%), and the SC-sense of the verb was mostly used following a SC-bias context (95.17%). When DO-sense was used, the percentage of DO-structure was greater (99.39%) than the percentage of SC-structures (0.29%), Z = -2.97, p = .003. When the verb was used in the SC-sense, the percentage of SC sentence completions (81.77%) was greater than the percentage of DO completions (15.20%), Z = -2.50, p = .01. These results demonstrate that the constructed context sentences cued one or the other verb sense, which influenced argument structure probability. Inspecting Table 4 allows for a comparison of results from this norming study with sense-based argument structure frequency norms gathered in an out-of-context norming study by Hare and colleagues (2003). Without the context manipulation participants were more likely to interpret a verb with a DO-sense (56.50%) than with a SC-sense (36.90%)[8]. Whereas the DO-sense of the verb was strongly biased for the DO-structure, the sense-based argument structure frequency of the SC-sense was less strong which may reflect the overall tendency for verb + DO in the English language. Overall, norms from the present norming study show that the context-biasing sentences performed well in creating a semantic scenario and activating one of the verb senses and structure, mitigating the overall DO preference. However, even when the verb was used in the SC-sense, a DO-structure was possible, i.e. it occurred in just over 15% of responses. All norming results for individual verbs are presented in Appendix D.1.

The second norming study aimed to examine whether including the noun phrase in the sentence fragments altered the sense and structure biases that were established in the first norming study. Since the noun phrases were developed to be plausible for either sense or structure of the verb, they should ideally not lead to different sentence completions as compared to the first norming study. Participants (N = 57, mean age = 40.62, range = 22-70)

[7] For details on the categorization of these structures see Table 1 in Hare et al. (2003).
[8] These completion norms for the 'verb without context norming study' reflect mean data of the ten verbs selected for the present experiment, and hence vary from Table 3 in Hare et al (2003) which presents the means of all twenty verbs used in the original study.

were provided with the same context sentences and target sentence fragments as above, but fragments included the post-verbal noun phrase (e.g. *When Billy went to the party he did not know any familiar faces. After a while he recognised* *his old friend*…). Participants were asked to complete the sentence. Construction of lists and filler items was identical to the first norming study. Results are shown in the second row of Table 4, and norming results for individual verbs are presented in Appendix D.2. In the SC-biased context, the presence of the noun phrase somewhat reduced the SC-biased use of the verbs ($U = 20$, $p = .02$), but with a prevalence of 84.79% it was still the dominant sense used. The inclusion of the noun phrase non-significantly increased the use of the SC-structure ($U = 40$, $p > 0.48$), and non-significantly decreased the use of the DO-structure ($U = 37.5$, $p > 0.35$). In the DO-bias condition, the noun phrase slightly increased the DO-biased sense of the verbs ($U = 26.5$, $p = .08$) whilst the use of the SC-structure increased non-significantly ($U = 44$, $p > 0.68$), and the use of the DO-structure decreased non-significantly ($U = 42$, $p > 0.57$). However, since previous research has shown that plausibility does not override the influence of argument structure frequency (Garnsey et al., 1997) these mild differences between the norming studies should not be a concern.

In summary, two norming studies demonstrated reliable associations between verb sense and argument structure frequencies in the verbs used in this experiment, supporting findings from the original study that was carried out in American English. Even though most of the sentences were altered to make them more accessible for people with aphasia, the present context sentences can bias a particular verb sense and its associated argument structure.

Table 4.
Use of DO-biased or SC-biased sense of verbs and structures in sentence completions (comparison of results from the verb following context and verb and NP following context)

	SC-biased context			**DO-biased context**		
	% Use of SC sense	**% SC structure**	**% DO structure**	**% Use of DO sense**	**% SC structure**	**% DO structure**
Context + verb	95.17	81.77	15.20	92.45	0.29	99.39
Context + verb + NP	84.79	87.80	2.94	96.67	4.81	94.39

2.2.3 Filler sentences and comprehension questions

Thirty filler sentences were created to hinder participants from forming expectations towards the sentence complement structures or guessing the nature of the task. Filler sentences were identical for each of the two experimental lists so that each list consisted of 20 target sentences and 30 filler sentences, plus the context sentences. Twenty filler sentences equally entailed verbs that can occur in the DO- and SC- sentence frame, but were designed to occur with a DO. This meant that there was an equal number of SC- and DO-sentences within the stimuli set, ensuring that readers did not develop anticipations for either structure apart from those generated from the context biases. The other ten filler sentences employed different structures, and were taken from the original experiment by Hare and colleagues. The contexts for the filler verb sentences never included any test verbs.

Each trial was followed by a yes/no question about the target sentence to guarantee that participants were reading the experimental sentences for comprehension and in order to gain off-line measurements of accuracy. The questions were designed to be simple and to avoid ambiguity. Comprehension questions were presented auditorily, recorded by a female native speaker of English who was blind to the answers of the questions.

2.3 Apparatus and Set-up

An EyeLink 1000 video-based eye tracker (SR Research, Ottawa, Ontario, Canada) was used. Eye gaze was tracked at a sampling rate of 500 Hz, using pupil and corneal reflection. Viewing was binocular but results were analysed from one eye only. The experimental set-up consisted of a Host PC that processed the camera data, a laptop that was connected to a 24-inch widescreen monitor to display linguistic stimuli, and a high-speed camera eye tracker sitting on an Eyelink 1000 desktop mount. A Microsoft sidewinder gamepad was utilised for recording answers to the yes/no questions, and an SR research chinrest was used to stabilise head movement. As the gamepad had a number of buttons, all non-meaningful buttons were covered with a self-setting rubber. Individuals with a right hemiparesis used the gamepad upside down as this helped utilising yes/no buttons with one hand. Participants were placed on a comfortable chair that was adjustable in height. The eye tracker sat in front of the display monitor and about 55cm away from the participants' eyes; viewing distance was 89cm. The stimuli sentences in lower and uppercase letters were presented in black Arial 14 point font on grey background, on a single line in the centre of the monitor. The visual angle of a letter was 0.3°.

2.4 Procedure

Participants completed two eye tracking sessions, testing the stimuli sentences in two separate presentation lists with a minimum of seven days between sessions. The four conditions were counterbalanced across the two lists: for each verb, one list contained the unambiguous SC-biasing context as well as the ambiguous DO-biasing context, and the other list contained the ambiguous SC-biasing context and the unambiguous DO-biasing context. This design guaranteed that participants read each context condition only once per list and per session, but meant that each verb occurred twice per list: in the ambiguous and unambiguous condition. The presentation of the lists was counterbalanced across participants and the order of sentences was pseudo-randomised so that experimental sentences were interspersed with filler sentences and a maximum of two experimental sentences were adjacent to each other. All together, participants read 20 experimental items and 30 filler items per session.

At the beginning of the session, participants were seated in front of the eye tracker and instructed to read sentences silently for comprehension at their own speed. They were told that they would be presented with two related sentences (the biasing context sentence and the target sentence) before they had to answer a comprehension question, which was presented both visually and via the loudspeakers. They were instructed to press a large button on the gamepad after they read the context sentence to reveal the target sentence, and after the target sentence to reveal the question. They were asked to press the left/right key to record their answer to the yes/no comprehension question. The context sentence and the target sentence were presented sequentially, followed by the comprehension question. To minimise head movements, participants placed their chin on the chinrest and their head onto the forehead rest. Calibration was done using a 9-point grid, trying to minimise average error to less than 0.5° and maximum error to less than 1° (as recommended by SR Research). The visual angle of a letter was 0.3° so that an error of 1° would be equal to showing fixations about 3 letters away from the location they occurred. Re-calibration was carried out whenever necessary during the experiment, and repeated at least once halfway through the experiment. Before the start of experimental trials, participants were presented with six practice trials, which included neither a target verb nor a SC-structure. Each trial commenced by showing a cross on the left side of the screen in order to direct eye gaze to the position of sentence beginning. Eye tracking sessions lasted between 30 and 60 minutes during which participants were given breaks whenever needed.

2.5 Overview of analyses

2.5.1 Regions of interest

Each sentence was divided into five regions (see Table 5). Region 1 was the verb and region 2 was the complementiser "that". Region 3 was the (ambiguous) noun phrase region, region 4 was the disambiguation region and hence the main region of interest, and region 5 was the post-disambiguation region. The five regions were always identical amongst the four conditions, except region 2 ("that") only existed for unambiguous trials. All regions except region 2 were analysed. As disclosed above, effects on early processing were mainly expected for the disambiguation region in which the ambiguity becomes apparent, but late effects resulting from re-reading patterns could be revealed in all regions.

Table 5.

Region		1 verb	2 complemen-tiser	3 noun phrase	4 disambiguation region	5 post-disambiguation region	
Sentence	...	recognised	(that)	his old friend	had adopted	a different	...

2.5.2 Measurements

Comprehension accuracy was measured to compare the groups' level of sentence comprehension, but comprehension questions were not designed to analyse parsing abilities. Eye movements were analysed to capture moment-to-moment processing of the experimental sentences, and to analyse influences of ambiguity and context. We calculated three different measures of processing time (first fixation durations, gaze duration and total fixation duration; see below for definitions) and one spatial-temporal measure (first-pass regression; see below for definition), all standard measures in eye movement research (Ashby et al., 2005; Boland, 2004; Rayner, 1998; Rayner et al., 2011, 2004).

2.5.3 Statistical analysis

For statistical analysis, models were conducted with R, version 3.3.2 (R Core Team, 2013), using the *lme4* package (Bates et al., 2015). To analyse accuracy of the comprehension questions and effects on first-pass regressions, we fit generalised linear-mixed effects models using *glmer*. We used binary data directly with the logit link function (accuracy dataset: 1 = correct; 0 = incorrect; first-pass regressions: 1 = trials includes regression; 0 = trial includes no regression). To analyse the other eye movement data, we constructed linear mixed-effects models using the *lmer* function. For both types of models, Group (NHI vs. PWA), Ambiguity (ambiguous vs. unambiguous) and Context (DO-bias vs. SC-bias) were entered as fixed effects. Further, the following interactions were included in the models: Group x Ambiguity, Group x Context, Ambiguity x Context, and Group x Ambiguity x Context. Random intercepts and slopes by participants and items were included for all fixed effects, as it was expected that participants and items would be differently affected by the experimental manipulation. This procedure corresponds to a maximal random effects structure, that is, all random slopes that were justified by the experimental design were included in a maximal model (Barr et al., 2013). Age was included as intercept in order to control for variability as a factor of age. Following Barr et al (2013), we used model selection techniques to test random slopes for inclusion in the model. Random slopes were reduced in a step-by-step fashion in order to find the best estimates for the given parameters. Once the random effect structure was determined, a full model with all fixed effects and the established random effect structure was built. It was reduced in a step-wise manner, and we used likelihood ratio tests to compare the goodness of fit of reduced models to the full model.

Since assumptions for linear mixed-effects models were not met, the measures were transformed using log transformations. Spearman tests were carried out using the coin package, which implements permutation-based tests (Hothorn et al., 2008). Graphs were built using the *ggplot2* function (Wickham, 2009). For each of the regions, models were constructed for each of the eye movement variables (first-fixation duration, gaze duration, total fixation duration and first-pass regressions).

2.5.4 Data filtering

As conventional in eye tracking research, eye movement data were filtered according to predetermined cut-offs (e.g. Juhasz & Rayner, 2006; Kliegl, Grabner, Rolfs, & Engbert, 2004; Rayner, Reichle, Stroud, Williams, & Pollatsek, 2006; Rayner et al., 2011; Schattka, Radach, & Huber, 2010). Fixations smaller than 80ms and adjacent to a larger neighbouring fixation (within 0.3° of a visual angle) were merged. Fixations shorter than 80ms that were not adjacent to a larger neighbouring fixation and fixations longer than 1200ms were excluded (Juhasz et al., 2006). Trials with gross track loss were also excluded, leading to an elimination of 4.47% of the data overall (3.68% for NHI and 4.80% for PWA). Trials with blinks were not excluded since a comparison of *trials with blinks* to *trials without blinks* showed no significant differences in gaze durations in a previous experiment (Huck, 2016).

3. Results

3.1 Accuracy

Overall, people with aphasia were less accurate (M = 87.61%, range = 69% - 100%) in answering the comprehension questions than the control group, which scored near ceiling on the task (M = 98.63%, range = 95% – 100%). The best fitted model with a fixed effect of Group and random intercepts of participants and items revealed a main effect of Group, β = -2.41, SE = 0.66, z = -3.66, p < 0.001. There were no interactions. Accuracy data are presented graphically in Figure 1 and individual scores are presented in Appendix B, Table B.1.

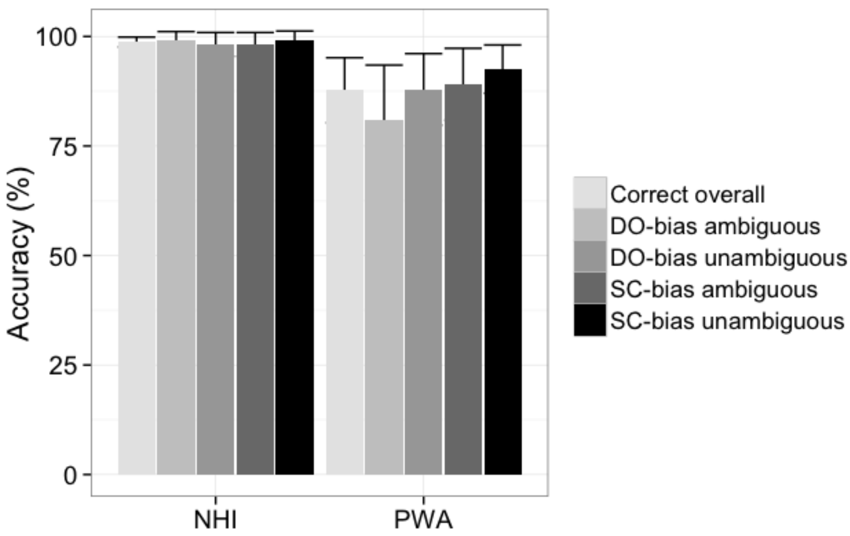


Figure 1. Accuracy of NHI and PWA in the eye-tracking task
(error bars represent standard deviations)

3.2 Eye movements

The following paragraphs summarise results from the analyses of eye movements based on the dataset including trials that were responded to either correctly or incorrectly. These results were only minimally different to the results based on correct trials only, but had more statistical power as the dataset was larger. Results are reported for each region separately, in the order that the regions occur in the sentence. The section starts with the early eye movement measurements, reporting first fixation and gaze durations. *First fixation duration* refers to the duration of the first fixation on a target region, given that it occurs before any fixations land on words further along in the text. *Gaze duration* was used as an additional measure of initial processing. Whereas first fixation duration refers to the first fixation only, gaze duration refers to the sum of all fixation durations in first-pass reading within a region of interest until a fixation is made to another area, which can be either progressive or regressive to the region of interest. Even though first fixation durations and gaze durations tend to be very similar in their outcome (Rayner, 1998), first fixation durations were additionally included in our analysis, because one of the aims of the experiment was to analyse the time course of processing. Next, results are reported for *total fixation duration* (also referred to as *total duration* or *total reading time*), which served as a measure of later cognitive processing or more global processing. It measures the duration of all fixations within the region of interest, both from first-pass and those from re-reading stages, and includes regressions to the region of interest (Rayner et al., 2004). When fixation duration varies from gaze duration, it reflects re-reading times. Finally, the probability of a *first-pass regression* (also referred to as *regressions-out*) was analysed as a spatial-temporal measure of first-pass reading and hence of early processing. It refers to the percentage of trials in which a regression, i.e. a fixation to a previous region, was made out of the region of interest after it had been fixated (Ashby et al., 2005). Even though an average of 10-20% of fixations in reading are regressive, the number of regressions by readers is determined by text difficulty (Rayner, 1998). Hence, it is likely that first-pass regressions will reflect the ambiguity manipulation, in other words, readers may be more likely to produce first-pass regressions if they experience a garden path sentence than if the sentence material is unambiguous. Measurements were only included in the analysis when a region of interest was fixated, but not if it was skipped. Overall, these measures were selected since both first-pass and second-pass reading had previously been shown to be sensitive to effects of ambiguity (Trueswell et al., 1993). Since the experiment by Hare et al was a moving-window self-paced reading study, the analysis of the time course of processing was limited to comparing experimental effects on early vs. late regions of the text. Analysing early and late eye movement measures will additionally differentiate early and late aspects of processing.

Figure 2 presents raw eye movement data. As can be seen in the Figure, the disambiguation region ("would probably") shows an increase in gaze and total fixation duration when trials were in the ambiguous DO-bias condition as compared to the other conditions. It is during the disambiguation region that the target structure becomes apparent, and the increased reading times suggest that readers misinterpreted the ambiguous noun phrase as the direct object of the target verb. The pattern of first-pass regressions is less clear, but indicates a sensitivity to the biasing sentence context with more first-pass regressions in the disambiguation region when the context sentence was DO-biasing than when it was SC-biasing.

Verb region

(He **acknowledged** (that) * his friends * would probably * help him * a lot.)

First fixation duration and gaze duration

The best-fitting models for first fixation duration and gaze duration contained fixed effects of Group and Ambiguity with an interaction term, and random intercepts for participants and items. Including Context as fixed effect did not improve model fit. The analysis of first fixation duration revealed an interaction between Group and Ambiguity, $\beta = 0.07$, $SE = 0.03$, $t = 2.22$, $p < .05$, in that PWA had significantly longer first fixation durations in the unambiguous verb region (M = 323ms) than in the ambiguous verb region (M = 285ms). The NHI on the other hand barely showed a difference between ambiguous (M = 302ms) and unambiguous trials (M = 293ms) when reading the verb. A main effect of Group was observed for gaze durations, $\beta = 0.18$, $SE = 0.05$, $t = 3.60$, $p < .01$, such that the average length was 350ms for NHI compared to 571ms for PWA.

Total fixation duration

The model with the best fit of the data for total fixation durations had Group and Ambiguity including an interaction term as fixed effects, and random intercepts for participants and items without random slopes. There was an effect of Group, $\beta = 0.37$, $SE = 0.07$, $t = 5.19$, $p < .0001$, with longer total fixation durations by the PWA (M = 1413ms) than by the NHI (M = 537ms). Further, the analysis revealed an effect of Ambiguity, $\beta = -0.10$, $SE = 0.03$, $t = -3.65$, $p < .001$. Overall, readers showed longer total fixation durations on the verbs in the ambiguous sentences (M = 1007ms) than in the unambiguous sentences (M = 952ms). However, an interaction between Group and Ambiguity ($\beta = 0.08$, $SE = 0.04$, $t = 2.21$, $p < .05$) demonstrated that the Ambiguity effect was driven by the NHI; Ambiguity was a main effect for NHI with longer total fixation durations on ambiguous trials (M = 589ms) than unambiguous trials (M = 486ms), $\beta = -0.10$, $SE = 0.03$, $t = -3.73$, $p < .001$, but Ambiguity did not affect total fixation durations by the PWA, $\beta = -0.01$, $SE = 0.03$, $t = -0.47$, $p > .05$.

First-pass regression

The best-fitting model for first-pass regressions included fixed effects of Group and Context and a random intercept for items. The only significant effect was a main effect of Group, $\beta = 2.30$, $SE = 0.29$, $z = 7.95$, $p < .0001$. Whereas the NHI showed a 4% probability of a first-pass regression out of the verb region, the probability of a first-pass regression was much higher if the reader had aphasia, with an average of 30% of first-pass regressions.

Summary

Overall, the groups differed in length of reading times and in the number of first-pass regressions, with the PWA showing an increase in number compared to the NHI. This suggests that the aphasia group is less efficient in reading than the NHI even in a sentence region prior to the ambiguity. While the NHI showed no sensitivity to the experimental manipulation with respect to early temporal eye movement measures, the analysis of the verb region revealed an unexpected effect of Ambiguity in the non-predicted direction for the PWA. The analysis of total fixation durations demonstrated an Ambiguity effect for NHI in the predicted direction.

(Ambiguous) noun phrase region

(He acknowledged (that) *** his friends *** would probably * help him * a lot.)

First fixation duration and gaze duration

For first fixation, the best-fitting model contained Group and Context (no interaction term) as fixed effects, and random intercepts for participants and items without random slopes. Group showed as a main effect for first fixation duration, $\beta = 0.08$, $SE = 0.02$, $t = 3.27$, $p < .01$. First fixation durations were longer by the PWA (M = 255ms) than the NHI (M = 206ms). For gaze durations, the best-fitting model had Group and Ambiguity plus an interaction term as fixed effects, and random intercepts for participants and items. Group was a main effect for gaze duration, $\beta = 0.21$, $SE = 0.05$, $t = 4.10$, $p < .001$; gaze durations were increased in the aphasia group (M = 471ms) in comparison to the control group (M = 271ms). There was an interaction between Group and Ambiguity, $\beta = -0.08$, $SE = 0.03$, $t = -2.42$, $p < .05$. Whilst there was no effect of Ambiguity for NHI, the aphasia group showed significantly longer gaze durations in ambiguous trials (M = 497ms) than unambiguous trials (M = 446ms), $\beta = -0.07$, $SE = 0.03$, $t = -2.64$, $p < .01$.

Total fixation durations

The best-fitting model had fixed effects of Group and Context, and the best random effects structure included random intercepts for participants and items. There was an effect of Group, $\beta = 0.45$, $SE = 0.07$, $t = 6.83$, $p < .0001$ such that total fixation durations by the PWA (M = 1235ms) were about three times longer than for the NHI (M = 399ms). Further the analysis of total fixation durations revealed a main effect of Context, $\beta = -0.06$, $SE = 0.02$, $t = -3.20$, $p < .01$, with longer total fixation durations in the DO-bias (M = 891ms) as compared to the SC-bias condition (M = 747ms).

First-pass regressions

The best-fitting model for first-pass regressions contained Group and Ambiguity and an interaction term as fixed effects, and a random intercept for participants. PWA demonstrated a significantly larger number of first-pass regressions (M = 34%) than NHI (M = 12%), $\beta = 1.48$, $SE = 0.44$, $z = 3.41$, $p < .001$.

Summary

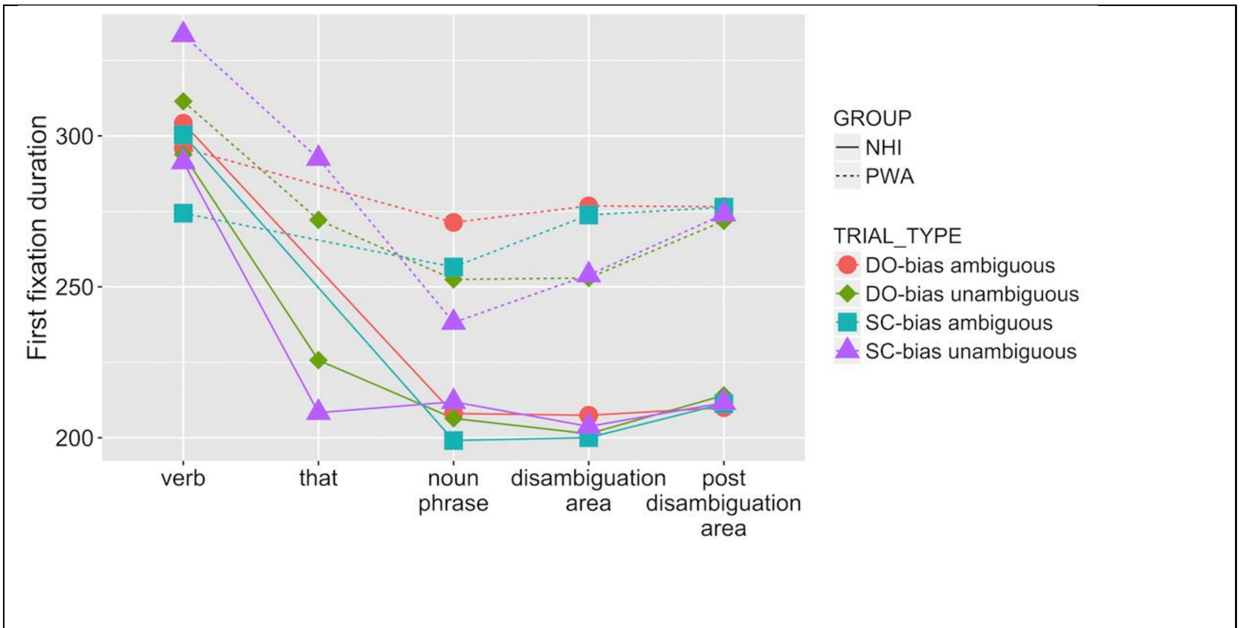
The analysis of the noun phrase region again demonstrated large group differences, with longer reading times and more first-pass regressions by the aphasia group as compared to the control group. Ambiguity affected gaze durations by the PWA but not the NHI. The early Ambiguity effect suggests that readers with aphasia were sensitive to whether the complementiser was present or omitted, as soon as they approached the noun phrase region. An effect of Context was significant for total fixation durations, and hence for a more global measure of reading.

Disambiguation region

(He acknowledged (that) * his friends * **would probably** * help him * a lot.)

First fixation duration and gaze duration

The best-fitted model for first fixation duration included fixed effects of Group and Ambiguity and an interaction term, as well as random intercepts for participants and items. The model revealed a main effect of Group, $\beta = 0.12$, $SE = 0.02$, $t = 4.92$, $p < .001$, with longer first fixation durations by the PWA (264ms) as compared to the NHI (M = 203ms). The best model for gaze durations included Group, Context and Ambiguity as fixed effects with an interaction term between Context and Ambiguity, and random intercepts. This again showed a main effect of Group ($\beta = 0.27$, $SE = 0.07$, $t = 3.77$, $p < .01$) with gaze durations by the aphasia group (M = 666ms) being more than double the duration of gaze durations by the control group (M = 292ms). There was also a main effect of Ambiguity, $\beta = -0.08$, $SE = 0.02$, $t = -4.57$ $p < .0001$, and a main effect of Context, $\beta = -0.06$, $SE = 0.02$, $t = -3.18$, $p < .01$. Further, the model revealed an interaction between Context and Ambiguity, $\beta = 0.06$, $SE = 0.03$, $t = 2.16$, $p < .05$. As can be seen in Figure 2, gaze durations were longer in the ambiguous ($M = 545$ms) than in the unambiguous condition ($M = 439$ms) when the context was DO-biasing ($\beta = -0.07$, $SE = 0.03$, $t = -2.54$, $p < .05$), but the difference between ambiguous and unambiguous sentences was small when the context sentence was SC-biasing ($t < 2$). Here, gaze durations were only slightly longer in the ambiguous condition ($M = 486$ms) than in the unambiguous condition ($M = 449$ms).



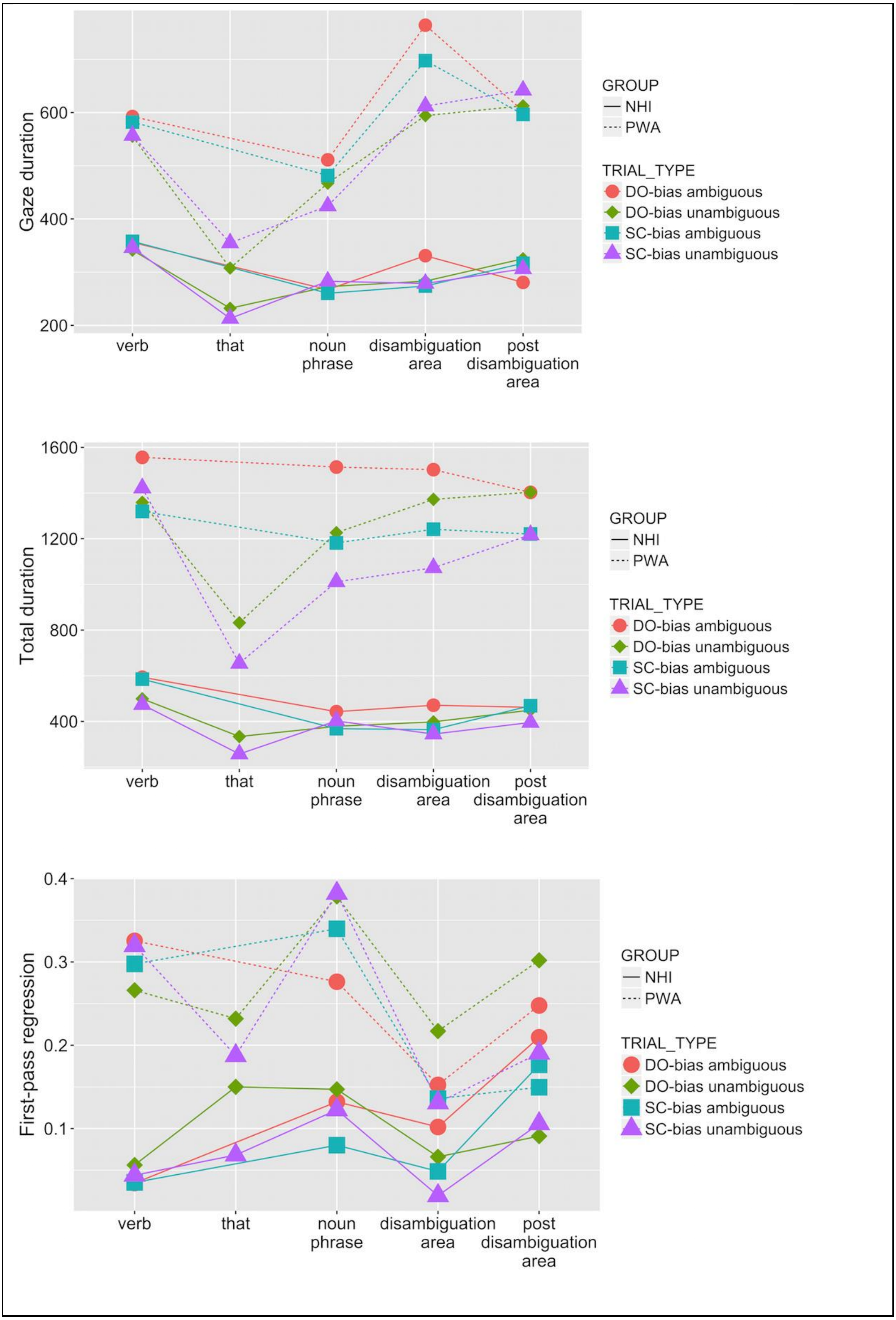

Gaze duration
600
400
200
verb
that
noun phrase
disambiguation area
post disambiguation area
GROUP
NHI
PWA
TRIAL_TYPE
DO-bias ambiguous
DO-bias unambiguous
SC-bias ambiguous
SC-bias unambiguous
Total duration
1600
1200
800
400
First-pass regression
0.4
0.3
0.2
0.1

Figure 2. Eye movements (First-fixation duration, Gaze duration, Total duration and First-pass regression) in all regions of interest, as a measure of sentence condition.

Total fixation durations

For total fixation durations, the best model had fixed effects of Group and Context (including interaction term), and random intercepts for participants and items. There was a main effect of Group, β = 0.49, *SE* = 0.06, *t* = 8.42, p < .0001, and a main effect of Context, β = -0.08, *SE* = 0.02, *t* = -3.68, p < .001. Total fixation durations were significantly longer in the aphasia group (*M* = 1297ms) than in the control group (*M* = 395ms). Across both ambiguous and unambiguous trials, total fixation durations were longer in the DO-bias conditions (*M* = 932ms) than in the SC-bias conditions (*M* = 759ms). There were no interactions.

First pass regressions

The model with the right level of complexity for this data had Group and Context as fixed effects (no interaction term), and a random intercept for item. The groups differed significantly in their proportion of first pass regressions, β = 1.12, *SE* = 0.25, *z* = 4.53, p < .0001. The PWA (*M* = 16%) made more regressions out of the disambiguation region than the NHI (*M* = 6%). There was also a main effect of Context, β = -0.54 *SE* = 0.23, *z* = -2.35, p < .05. Readers made more first-pass regressions when the sentence followed a DO-bias context (M = 13%) than when the sentence followed a SC-bias context (M = 8%).

Summary

Similarly to the analyses of the other regions, groups differed significantly in eye movement measures. PWA had increased first fixation durations, gaze durations, total fixation durations, and more first pass regressions than NHI. In terms of the research questions, the analyses of the disambiguation region revealed effects of both Ambiguity and Context, suggesting that readers from both groups were sensitive to whether the complementiser was present or omitted, and to whether the context sentence biased them towards a DO-sense and structure of the verb, or an SC-sense and structure. An interaction between Ambiguity and Context for gaze duration indicates that both PWA and NHI had most pronounced difficulties processing the disambiguation region when there was no 'that' and when the context sentence promoted the DO-sense and structure, which turned out to be incorrect.

Post disambiguation region

(He acknowledged (that) * his friends * would probably *** help him *** a lot.)

First fixation duration and gaze duration

The model that had the right level of complexity for first fixation durations and also for gaze durations included Group and Ambiguity as fixed effects with an interaction term between them, and random intercepts for participants and items. Adding Context as a fixed effect did not improve model fit. Group was significant as a main effect for first fixation durations, β = 0.11 *SE* = 0.02, *t* = 5.31, p < .0001, and for gaze durations, β = 0.25 *SE* = 0.06, *t* = 4.23, p < .001. First fixation durations were longer by the PWA (M = 275ms) than the NHI (M = 212ms), and also gaze durations were increased in the aphasia group (M = 613ms) as compared to the control group (M = 307ms). The effect of Ambiguity was not significant.

Total fixation durations

The best model had fixed effects of Group and Context (without an interaction term), and random intercepts for participants and items. Adding Ambiguity as a fixed effect did not improve the model. Total durations yielded main effects of Group, β = 0.45, *SE* = 0.05, *t* = 9.57, p < .0001, and of Context, β = -0.04 *SE* = 0.02, *t* = -2.62, p < .01. The PWA had total durations (*M* = 1312ms) that were almost triple the duration of those by the NHI (*M* = 444ms). Across ambiguous and unambiguous sentences, total durations in the DO-biasing context were longer (*M* = 929ms) than in the SC-biasing context (*M* = 831ms).

First-pass regressions

The best fitting model for first-pass regressions had fixed effects of Group and Ambiguity including an interaction term, and a random intercept by items. There was a main effect of Ambiguity, β = -0.81 *SE* = 0.29, *z* = -2.78, p < .01, with an increase in first-pass regressions in the ambiguous trials (M = 20%) as compared to the unambiguous trials (M = 17%). However, an interaction between Group and Ambiguity (β = 1.10 *SE* = 0.38, *z* = 2.93, p < .01) revealed that the Ambiguity effect only emerged for the control participants (β = -0.88 *SE* = 0.38, *z* = -2.92, p < .01) but not the participants with aphasia (*z* < 2). The NHI showed 19% of first-pass regressions out of ambiguous trials compared to 10% out of unambiguous trials. The PWA on the other hand made 20% first-pas regressions out of ambiguous sentences and 25% out of unambiguous sentences.

Summary

In summary, the analyses of the post disambiguation region demonstrated, i) Group effects for all three temporal measures suggesting that the aphasia group took longer to read the post disambiguation region than the control group, ii) a Context effect for total fixation durations, and iii) an Ambiguity effect on first-pass regressions for the NHI only. Overall, we conclude that NHI notice the ambiguity when they read the post disambiguation region in first-pass whereas the PWA are unaffected by the ambiguity in this later sentence region. Readers from both groups are still affected by the Context bias when they read past the disambiguation region. [9]

3.3 Subgroup analysis of the participants with aphasia who showed a discrepancy between canonical and non-canonical sentence comprehension

Aphasia participants who showed a discrepancy between canonical and non-canonical sentence comprehension might perform differently with respect to the full eye-tracking study. A difficulty understanding non-canonical sentences is often part of an agrammatic profile, which has been linked to distinct sentence comprehension patterns. In order to identify potential differences, an additional analysis of this subgroup was conducted (PWA ID 1, 3, 4, 7, 9, 11), using the same procedures with linear mixed models as above.

Differences as compared to the results of the full dataset were as follows. For the verb region, there was no effect of Group, Ambiguity or Context on first fixation duration whereas the analysis of data from the full group demonstrated an interaction between Group and Ambiguity. For total fixation duration, there was an interaction between Group and Ambiguity that was only marginally significant for the subgroup analysis (β = 0.08, SE = 0.04, t = 1.96, p = .05) even though it was significant in the full group analysis. For the noun phrase region, results were the same. For the disambiguation region, there was no interaction between Ambiguity and Context for gaze duration for the subgroup analysis as compared to the full group analysis, but main effects of Group, Ambiguity and Context were equal. Further, the subgroup did not show a significant increase of first-pass regressions as compared to the full group. The analysis of the other measurements yielded the same results. For the post disambiguation region, the analysis of the subgroup only showed a main effect of Group, but no main effect of Context as in the analysis of the full group. In summary, the analyses do not indicate substantial differences in the performance of this subgroup as compared to the full sample of participants with aphasia. Main effects of Ambiguity and Context were found for the subgroup of participants who had a

[9] "As suggested by an anonymous reviewer, data were also analysed excluding the participant diagnosed with Broca's aphasia (ID = 2). Since this subtype is associated with more severe sentence comprehension difficulties than the other subtypes, it could be expected that this individual processes the experimental sentences differently as compared to the rest of the group. The only difference revealed was in the noun phrase region for total fixation durations. Here, the analysis of the dataset excluding ID 2 demonstrated a main effect of Group (β = -0.44, SE = 0.07, t = 6.44, p < .0001), Ambiguity (β = -0.09, SE = 0.02, t = -3.42, p < .001), Context (β = -0.09, SE = 0.02, t = -3.40, p < .001), and an interaction between Ambiguity and Context (β = 0.07, SE = 0.04, t = 2.05, p < .05). For the DO-biasing contexts, total fixation durations were longer in the ambiguous (M = 951ms) than in the unambiguous (M = 767ms) trials. For the SC-biasing contexts, total fixation durations were also longer in the ambiguous (M = 756ms) than in the unambiguous (M = 699ms) trials, but the ambiguity effect was less pronounced. Hence, if the individual with Broca's aphasia was excluded, the data showed slightly stronger effects in the predicted direction in a measure that represents fixations from all processing stages."

discrepancy between canonical and non-canonical sentence comprehension as well as for the full group of participants with aphasia.

3.4 Individual analysis of the PWA and correlation with results from language assessments

Further analyses were carried out to investigate whether PWA show individual differences in their sensitivity to the ambiguity and context effects, and whether or not potential differences are related to their underlying language profile. This analysis was based on eye movement data from the disambiguation region as the main region of interest. Individual effects of ambiguity and context were calculated for gaze and total fixation durations, in order to derive information from one early and one late measure of processing. For the difference score in ambiguity, fixation durations in the unambiguous condition were subtracted from fixation durations in the ambiguous condition, and for the context difference score, fixation durations in the SC-bias condition were subtracted from fixation durations in the DO-bias conditions. Negative scores represent scores in the non-predicted direction. Individual difference scores are presented in Appendix B, Table B.2. Most participants with aphasia were sensitive to the experimental manipulations, but while the difference scores of ambiguity were similar between gaze and total fixation durations, the difference scores of context were more pronounced in total fixation duration as compared to gaze duration. Next to the variability depending on the eye movement measure there was also individual variability. A small number of individuals with aphasia revealed reverse effects. Most of the reverse scores were small and may present noise, but some individuals had more pronounced negative scores; ID 9 demonstrated a reading advantage for ambiguous trials over unambiguous trials for total fixation durations, and ID 11 showed shorter gaze and total fixation durations on trials with DO-bias contexts.

Correlation analyses were run to analyse whether there was an association between aphasia severity (AQ), the language composite scores or working memory scores and the magnitude of the effect scores. This revealed a significant relationship between the WAB AQ and the Ambiguity effect for gaze duration, $r = -.76$, $p < .01$. The higher the AQ, the smaller the effect of Ambiguity in gaze duration. Further, there was a marginally significant relationship between the lexical-semantics written comprehension composite score from the background assessments and the Context effect in gaze duration, $r = .67$, $p < .05$. Reduced lexical-semantic skills were associated with a smaller Context effect for gaze duration. However, this correlation may have largely been driven by ID 11 who had a lexical-semantics written comprehension composite score of .84 and a context effect of -233, which represents an unexpected advantage of target sentences following the DO-bias over sentences following the SC-bias. There was no significant association between the lexical-semantics composite score (which includes lexical production tasks), the sentence comprehension composite score, or working memory skills and the experimental effects. All results (significant and non-significant) are located in the Appendix, Table B.3.

3.5 Summary of the main results and discussion

The aim of this study was to investigate whether readers with aphasia and neurologically healthy readers are influenced by a verb's sense-based argument structure frequency (measured as a Context effect) and/or the presence or absence of the complementiser *that* (measured as an Ambiguity effect) when they read sentences of the DO/SC ambiguity type. Results from the accuracy analyses demonstrated that the NHI scored near ceiling in all conditions whereas the PWA showed mild difficulties understanding the sentences. Even though the participants with aphasia had the lowest accuracy scores in the ambiguous DO-bias condition, there was no significant effect of ambiguity or context on accuracy.

Results from the eye movement analyses from the disambiguation region revealed that processing by both groups was influenced by the sense-biasing contexts. Participants showed longer reading times when the context sentence was DO-biasing (e.g. *When Billy went to the party he did not know any familiar faces. After a while he recognised (that) his old friend <u>had adopted</u> a different look and appeared completely different.*) than when it was SC-biasing (e.g. *Gordon had moved in with his old friend, but they argued a lot. After a while he recognised (that) his old friend <u>had adopted</u> a different lifestyle and living together would not work out.*). In line with previous work by Hare and colleagues (2003), our interpretation is that the DO-biasing condition primed readers for the concrete meaning of *recognise*, that is 'to detect with the senses'. This led readers to expect a direct object in the target sentence, which is the structure that is most frequently associated with the concrete meaning of *recognise*. However, since the structure was a SC-complement, misanalysis occurred, leading to prolonged reading times and a higher probability of fist-pass regressions in the region *had adopted*. The increase in first-pass regressions in sentences following the DO-bias may indicate a checking behaviour by the readers who expected a DO structure. The context effect showed early (significant effect for first-pass regressions and gaze durations) and lasted, as revealed in later measures (significant effect for total fixation durations) and in the post disambiguation region. In contrast to the DO-biasing condition, the SC-biasing condition primed readers for the abstract meaning of *recognise*, that is 'be fully aware or cognizant of', which is the structure that probabilistically aligns with the abstract meaning. Processing was not interrupted or interrupted to a lesser extent, as the expected SC-structure was consistent with the target argument structure.

Next to the context effect, eye movement analyses from the disambiguation region showed that readers from both groups were sensitive to the SC/DO ambiguity. Reading times were longer on ambiguous trials (e.g. *After a while he recognised his old friend had adopted a different look and appeared completely different.*) than on unambiguous trials (e.g. *After a while he recognised that his old friend had adopted a different look and appeared completely different.*). As expected, this result indicates that the complementiser *that* signalled a complement structure and its absence caused processing disruptions. The ambiguity effect showed early, as an effect on gaze duration in the disambiguation region for both groups. There was also an effect of ambiguity on first-pass regressions for the control participants in the analysis of the post disambiguation region. However, ambiguity was not a significant effect for total fixation durations, suggesting that the effect of ambiguity did not last as long as the effect of context.

The extent to which the people with aphasia were sensitive to the context and ambiguity manipulations in first pass reading varied, and effects were mildly associated with some of the language assessment scores. However, none of these relationships were strong.

4. General discussion

4.1 The influence of meaning-structure correlations on reading

Results revealed that the knowledge of sense-contingent argument structure frequencies influenced reading in both groups of readers. As was predicted, eye movements by the NHI and the PWA were influenced by context and ambiguity. Regarding the aphasia group, this result is particularly interesting as the sentence complement argument structure is the more complex sentence type, and both on- and off-line processing in aphasia has been shown to be influenced by structural complexity (Caplan et al., 2007; Knilans and DeDe, 2015). The present study demonstrated that the difficulty of reading and understanding a sentence complement structure was mitigated by the presence of a context that promoted that structure, and further, that readers were indeed able to access correlations between verb meaning and structure. In other words, readers processed structures that frequently co-occur with certain verb meanings faster than structures that are less likely to occur with those verb meanings. Another possibility for the lack of finding a complexity effect for the PWA in this study could be that the participants in this study mostly had mild sentence comprehension difficulties, and hence less difficulties in processing complex sentence complement sentences. It is not clear whether a context sentence mitigates the processing of a more complex sentence structure if people have more severe deficits in sentence comprehension. NHI and PWA were also sensitive to the ambiguity manipulation when they read the disambiguation region, suggesting that they experienced a garden-path effect when the complementiser *that*, which is a strong cue for the SC-structure, is omitted. Essentially, an interaction between Context and Ambiguity in first pass reading demonstrates that the Ambiguity effect was only significant for sentences following the DO-bias. Hence, readers were able to use the context cue to override the structural ambiguity.

For unimpaired processing, findings from this study are consistent with the results from the original study by Hare and colleagues (2003). The original study revealed main effects of the context prime and of ambiguity in the segments corresponding to the disambiguation region, and these main effects were qualified by an interaction with the ambiguity effect only occurring in sentences following a misleading prime. The present study equally showed this interaction in the disambiguation region for first-pass reading. Results from our study suggest that PWA, in parallel to NHI, were affected by meaning structure correlations in an early stage of processing. Differences between results from this study and the original study are that some effects were found in sentence regions in addition to the disambiguation region. This variance is most likely due to our method used, as eye tracking captures natural reading that does not constrain participants to processing one segment at a time.

Regarding the aphasia group, results support previous research showing that knowledge of statistical regularities between lexical and structural forms are resilient to breakdown in aphasia and can facilitate sentence comprehension (DeDe, 2013a, 2013b, 2012, 2008, Gahl, 2002, 2000; Gahl et al., 2003). In line with the Lexical Bias Hypothesis, the influence of verb bias on the comprehension of syntactically simple sentences has previously been shown in auditory comprehension (Gahl, 2002, 2000; Gahl et al., 2003), as well as in reading (DeDe, 2013a). The current study extends claims of the Lexical Bias Hypothesis by illustrating that probabilistic factors also facilitate the interpretation of structurally complex sentences with and without a syntactic ambiguity, adding to results from two previous studies on the processing of temporal ambiguities in aphasia (DeDe, 2013b, 2012). The evidence suggests that probabilistic factors not only influence the processing rate, but also syntactic decoding. This result is further consistent with two recent studies, which found that PWA can, at least under some conditions, use cues to predict an upcoming sentence structure, facilitating the reading of that region (Hanne et al., 2015; Warren et al., 2016). To our knowledge this is the first study showing that probabilities that influence sentence processing in aphasia can be as subtle as presenting a link between structure and verb sense. Finding that these form-meaning pairings are resilient to disruptions of at least mild language impairment points to the fact that they are tightly engrained in the lexical representation of a verb. This is consistent with exemplar-based models that assume that information needed for sentence processing is not accessed via rules but is accessed as a representation in memory (Bod, 2006). The assumption is that speakers store specific examples of linguistic experiences, and during the process of sentence comprehension, we draw on such exemplars from memory (Bod, 2006).

However, not all results were aligned with our predictions. Based on results from a previous study (DeDe, 2013a), it was expected that the ambiguity effect would be reduced in comparison to the context effect. In the self-paced reading study, the PWA showed a delayed effect of ambiguity in comparison to the NHI. The control participants showed an effect of ambiguity when reading the complementiser *that* while the participants with aphasia did not show sensitivity to ambiguity until the ambiguous noun phrase. DeDe argued that this was due to the PWA being delayed in processing closed-class words such as the complementiser *that*. In this study we did not analyse eye movements on the complementiser *that* so no comparisons to Dede's study can be made with respect to this region. However, contrary to predictions, there were no results from the analyses of other regions that would suggest that PWA were delayed in accessing *that* in comparison to NHI. Both groups were influenced by ambiguity in early measures that are associated with lexical access. Additionally, in the self-paced reading study by DeDe (2013a), PWA were significantly influenced by the sense-independent verb bias for both ambiguous and non-ambiguous trials whereas NHI were influenced by the ambiguity. No such significant group difference was found in the present study on sense-contingent verb bias. Differences between results from this study and results from the self-paced reading study could be task-related. As argued by Knilans and DeDe, the method of self-paced reading prevents backtracking whereas eye tracking allows participants to use different reading strategies (Knilans and DeDe, 2015). This would suggest that total fixation durations, which sum up all fixation durations in a region, are the eye movement measure that is most similar to self-paced reading times. The analysis of total fixation durations in the disambiguation region in this study showed an effect of group and context, but no effect of ambiguity, a result that is more similar to the finding for the aphasia group by DeDe (2013a). On the other hand, results from total fixation durations were not consistent with the finding of an ambiguity effect for the NHI only. More research is needed to understand the differences between these methodologies of reading better.

4.2 Group differences

Experimental effects on reading by both groups of participants were similar. There were some subtle differences with respect to which regions of the sentence showed ambiguity effects, which might point to differences in the time course of processing. However, it is difficult to form strong conclusions here. Both groups showed effects in the crucial disambiguation region and in first pass reading. Thus PWA, like controls, were using 'that' to formulate rapid structural predictions. Conclusions about context were similar. Both groups responded to this cue, showing that they were using context to make predictions about which verb meaning and associated verb structure was being used.

Independent of the experimental effects, however, group differences were strong and were revealed on all measures. These effects showed that PWA had increased first fixation durations, gaze durations and total fixation durations, and demonstrated more first-pass regressions than the NHI. Increased reading times and a larger number of regressions are indicative of processing difficulties (Boland, 2004; Rayner, 1998). The most pronounced group differences were found in total fixation durations, which combine all fixations within a region, including first-pass and re-reading durations. This suggests that the aphasia group needed additional time in re-reading, reflecting difficulties in syntactic parsing or end-of-clause integrative processes (Knilans and DeDe, 2015). Thus, even though the PWA showed relatively mild language impairments in the language background tests, they required more time and more revisions than healthy readers.

Although eye movement measures evidenced a slowed time course of processing for the PWA, the experimental effects were not shown in a later region compared to the NHI. A previous study of the auditory comprehension of early-closure ambiguities demonstrated that when PWA tried to disambiguate, they showed an effect of lexical and prosodic cues in a region later than the NHI (DeDe, 2012b). Also studies using eye tracking whilst listening observed that the PWA show effects in a later region as compared to the controls, and sometimes after sentence offset (Bos et al., 2014; Choy and Thompson, 2010; Dickey et al., 2007; Dickey and Thompson, 2009; Hanne et al., 2011; Meyer et al., 2012). Finally, listening studies on predictive processes in aphasia demonstrated that predictive processing is delayed in comparison to neurologically healthy controls. Mack et al (2013) demonstrated that effects of verb meaning on the prediction of a following noun phrase argument occurs substantially later than for control participants. In their study, participants listened to sentences containing a restrictive or unrestrictive verb (omitting the noun phrase argument), and showed increased fixation proportions to the target picture depicting the noun phrase that is appropriate following the restrictive verb in the restrictive verb condition. While the control participants showed this effect within 500ms after verb offset, the people with aphasia showed this in the time window between 1000-1500ms after verb offset. The reasons that studies in auditory comprehension show experimental effects in later region for the PWA compared to the NHI is likely because it is not possible control the speed of the input (DeDe, 2013a). During written sentence comprehension on the other hand, the reader can determine the rate of information intake, and can move the eyes back and forth in the text. Even though effects in reading can spill over to other regions (Calvo and Meseguer, 2002; Pollatsek et al., 2008), prolonged reading times are evidence for delayed processing, and they typically show in the region that creates the difficulty.

4.3 Individual differences

The second aim of this study was to examine whether the PWA show any individual differences in terms of ambiguity and context effects, and if yes, whether these can be related to their underlying language profile. The analysis of individual differences demonstrated a relationship between aphasia severity and the ambiguity effect in first pass reading, suggesting that readers with a lower AQ showed more pronounced ambiguity effects. This means that individuals with moderate aphasia may have over-relied on the cue from the complementiser in comparison to readers with mild aphasia, and that they had more difficulties in overcoming the structural ambiguity in an early stage of processing. This finding is consistent with a study of structural ambiguity in the healthy population which demonstrated that the magnitude of ambiguity effects can be dependent on lexical knowledge (Traxler and Tooley, 2007). Traxler and Tooley found that the better the vocabulary knowledge of their participants was, the smaller was their ambiguity effect.

Correlation analyses further indicate that variability in using the context cue in first pass reading may be related to lexical-semantic skills in written comprehension. Reduced lexical-semantic skills were associated with a smaller context effect in first pass reading in the eye-tracking experiment. In other words, individuals with aphasia who had reduced lexical-semantic skills may have experienced difficulties using the context sentence promptly to access meaning-structure correlations. In contrast, no significant relationship was found between lexical-semantic skill and total fixation duration which may indicate that individuals with mildly compromised lexical-semantic skills are able to access subtle differences in verb sense and their probabilistically associated argument structure frequencies, but that it takes more time. It has to be emphasized, however, that the correlation analyses were limited since the aphasia group did not show much variation in their scores.

It is more difficult to account for the finding from the analysis of the disambiguation region that one individual with aphasia demonstrated a large processing advantage for ambiguous sentences (for total fixation durations), and one for sentences following the DO-context sentence. We assume that these effects represent noise, or that they may be related to a sense-independent verb bias that led to a processing advantage of sentences that correspond to a DO-structure. The participants may have interpreted the noun phrase as direct object when reading the disambiguation region, not yet experiencing the misanalysis. A global transitivity bias was previously reflected in two studies involving the resolution of sentences with a temporal ambiguity in aphasia (DeDe, 2012b, 2013a). The study on the comprehension of ambiguous early closure sentences (DeDe, 2012b), for example, showed that the PWA showed prolonged listening times in the ambiguous noun phrase region when the cues biased against the preferred S, V, O structure (*While the parents* ***danced*** <u>*the child*</u> *sang a song with her grandmother*).

In summary, results indicate that mild impairments of language processing (lexical-semantic skills and aphasia severity) may lead to subtle differences in the time course of processing the sentence cues. Differences showed in first pass processing but not in a measure of global reading. Nevertheless, findings warrant caution as results are based on a small number of individuals with aphasia that were limited in the range of language impairment. More research is required in this area, including individuals with more pronounced compromises of language processing.

4.4 Conclusion

The present eye tracking study established that reading and syntactic decoding by both the people with aphasia as well as the neurologically healthy participants is influenced by sense-contingent argument structure frequencies, and hence by factors relating to our language exposure. While this outcome indicates that groups process sentences similarly, there were also some group differences. The aphasia group showed delayed and less efficient processing as demonstrated by longer reading times and by a strong increase in regressions to previous sentence regions. Overall, findings support and extend the Lexical Bias Hypothesis and evidence presented in previous studies, suggesting that PWA have a processing advantage when they can exploit highly frequent meaning-structure correlations, but that they have larger processing disruptions when sentences conflict with the frequent meaning-structure correlations. However, the delay in processing makes sentence comprehension in aphasia less efficient as compared to neurologically healthy individuals. Further research is needed to understand how people with aphasia process information from different types of frequencies, and how this relates to aphasia severity and the underlying lexical-semantic and syntactic impairment. Additionally, it would be insightful to investigate the influence of probabilistic factors on other types of syntactic ambiguity.

Appendix A. Individual language assessment scores for people with aphasia.

Table A.1. Individual (and mean) scores on the Western Aphasia Battery-Revised

PWA ID	Spontaneous Speech (max=20)	Auditory Comprehension (max=10)	Repetition (max=10)	Naming (max= 10)	Aphasia Quotient (max= 100)	WAB Subtype (Clinical Picture)	Aphasia Severity
1	17	10	8.2	9.5	89.4	Anomic	mild
2	12	5.95	6	8.9	65.7	Broca	moderate
3	15	7.95	4.8	7	69.5	Conduction	moderate
4	18	9.15	7.2	7.1	82.9	Anomic	mild
5	17	9.9	9	9.1	90	Anomic	mild
6	17	10	9.3	9.5	91.6	Anomic	mild
7	14	8.7	6.4	9.2	76.6	Conduction (Broca)[a]	mild
8	17	10	9.6	8.7	90.6	Anomic	mild
9	19	9.95	9.1	8.9	93.9	Anomic	mild
10	14	9.8	8.6	9	82.8	Anomic	mild
11	15	9.4	9.2	8.5	84.2	Anomic (Broca)[b]	mild
Mean	15.91	9.16	7.95	8.67	n.a.	n.a.	n.a.
SD	2.07	1.25	1.60	0.86	n.a.	n.a.	n.a.

[a] ID 7 was classified with Conduction Aphasia. However, she had symptoms of Broca's aphasia such as non-fluent speech with omissions of determiners as well as inflection errors.

[b] ID 11 had a history of Broca's Aphasia. At the time of testing her speech still had some characteristics of Broca's Aphasia, but she had good monitoring skills and made few errors. Agrammatism was more evident in sentence comprehension with a superior performance in canonical as compared to non-canonical sentences (Table A.3)

Table A.2. Individual (and mean) scores on lexical-semantic processing (all in %)

PWA ID	Word - picture matching (PALPA)	Visual lexical decision (PALPA)	Lexical-semantics written comprehension Composite score	Object (noun) naming (PALPA)	Action (verb) naming (VAST)	Lexical Production (VAST)	Lexical-semantics composite score
1	100	100	100	95	79	87	93
2	93	91	92	87	68	77	85
3	95	93	94	83	68	76	85
4	98	87	93	92	65	78	85
5	100	93	97	100	91	95	96
6	98	89	94	100	98	99	96
7	100	100	100	95	65	80	90
8	98	94	96	95	80	88	92
9	93	99	96	93	80	87	91
10	100	100	100	98	95	97	98
11	93	74	84	85	71	78	81
Mean	97	93	95	93	78	85	90
SD	3.02	7.75	4.66	5.80	12.06	8.49	5.53

Note: Columns representing composite scores are shaded in grey.
Lexical-semantics written comprehension composite score = average of word-picture matching and visual lexical decision; lexical-semantics composite score = average of lexical-semantics written comprehension composite score and lexical production score

Table A.3. Individual (and mean) scores on sentence comprehension (in %) and working memory (span score)

PWA ID	Sentence -picture matching (PALPA)	Total canonical (VAST)	Total non-canonical (VAST)	Sentence comprehension composite score	WM digit forward (Wechsler)	WM digit backward (Wechsler)	WM sentence span (based on Caspari et al., 1998)
1	88	100	65	85	5	5	4.0
2	73	85	80	78	4	4	3.5
3	85	85	65	80	2	3	5.5
4	75	90	40	70	4	3	2.5
5	95	100	90	95	4	3	4.5
6	98	95	85	94	5	3	6.0
7	77	95	75	81	4	3	4.0
8	97	100	90	96	7	4	4.5
9	87	100	70	86	7	5	5.0
10	90	95	90	91	5	3	6.0
11	83	95	35	74	8	3	2.5
Mean	86	95	71	85	5	3.55	4.36
SD	8.65	5.68	19.25	8.79	1.73	0.82	1.23

Note: Column representing composite score is shaded in grey.
Sentence comprehension composite score = average of sentence-picture matching, total canonical and total non-canonical.

Appendix B. Comprehension accuracy and individual effect scores in the eye tracking experiment

Table B.1.
Accuracy as a function of sentence condition and participant (in %)

ID	DO-bias ambiguous		DO-bias unambiguous		SC-bias ambiguous		SC-bias unambiguou s		Correct overall	
	Group NHI	PWA	NHI	PWA	NHI	PWA	NHI	PWA	NHI	PWA
1	90	100	100	100	100	100	100	100	98	100
2	100	70	100	90	100	90	100	90	100	85
3	100	50	90	67	100	70	100	90	97	69
4	100	90	100	90	90	70	89	78	95	82
5	100	100	100	100	100	100	100	100	100	100
6	100	90	100	80	100	100	100	100	100	93
7	100	80	100	100	100	100	100	090	100	93
8	100	70	100	80	100	90	100	100	100	85
9	100	90	100	90	90	80	100	90	98	88
10	100	100	90	100	100	100	100	100	98	100
11	100	50	100	70	100	80	100	80	100	70
Mean	99	81	98	88	98	89	99	93	99	88
SD	3.02	18.68	4.05	12.17	4.05	12.21	3.32	8.20	1.68	11.05

Table B.2.
Individual (and mean) Ambiguity and Context effects for gaze and total fixation duration for people with aphasia (difference scores).

PWA	Ambiguity Effect Gaze duration	Ambiguity Effect Total fixation duration	Context Effect Gaze duration	Context Effect Total fixation duration
1	-4.11	197.3	75.71	599.7
2	375.11	316.33	106.89	535.33
3	308.19	671.04	52.90	0.58
4	-9.08	208.34	-56.62	338.14
5	74.33	-133.1	-91.23	704.3
6	96.77	1412.34	68.46	1624.53
7	394.30	891.58	208.57	769.05
8	95.71	281.90	-51.37	96.85
9	24.13	-381.38	23.20	674.49
10	69.16	51.4	25.70	46.2
11	329.32	326.64	-233.02	-210.29
Mean	159.43	349.31	11.75	470.81
SD	157.96	493.16	116.74	505.92

Table B.3.
The relationship between language and working memory skills and individual effects of Context and Ambiguity for gaze and total fixation durations

	Context effect gaze duration		**Ambiguity effect gaze duration**		**Context effect total fixation duration**		**Ambiguity Effect total fixation duration**	
	r	**p**	**r**	**p**	**r**	**p**	**r**	**p**
WAB AQ (severity)	ns	ns	-.76	.007	ns	ns	ns	ns
Lexical-semantics written comprehension	.67	.02	ns	ns	ns	ns	ns	ns
Lexical-semantics	ns	ns	ns	ns	ns	ns	ns	ns
Sentence comprehension	ns	ns	ns	ns	ns	ns	ns	ns
WM digit score forward	ns	ns	ns	ns	ns	ns	ns	ns
WM digit score backward	ns	ns	ns	ns	ns	ns	ns	ns
WM sentence span	ns	ns	ns	ns	ns	ns	ns	ns

Note: r = Pearson's correlation test

Appendix C. Stimuli sentences and sense keys used in the eye tracking experiment.

Table C.1.
Experimental stimuli with context sentences and sense keys from WordNet

Target verb	SC clause	Condition and target sense of the verb according to WordNet
acknow-ledge	Context biasing towards SC	**acknowledge#1** (declare to be true or admit the existence or reality or truth of)
	For an hour John was bragging that he could move house on his own even though that was silly. (1) Finally though, he acknowledged that **his friends would probably help him** a lot. (2) Finally though, he acknowledged **his friends would probably help him** a lot.	(1) SC bias non-ambiguous (2) SC bias ambiguous In the end, did John think his friends would help? (yes)
	Context biasing towards DO	**acknowledge#4**, recognise#7, recognise#5 (express obligation, thanks, or gratitude for)
	Alex saw his friends sitting down in the first row to watch him in the competitive race. (3) Finally, he acknowledged that **his friends would probably help him** a lot. (4) He acknowledged **his friends would probably help him** a lot.	(3) DO bias non-ambiguous (4) DO bias ambiguous Did Alex think his friends would make it worse? (no)
add	Context biasing SC	**add#2**, append#3, supply#4 (state or say further)
	George suggested reasons for the children's poor grades at school recently. (1) He added that **the children were probably better off** doing fewer after-school activities. (2) He added **the children were probably better off** doing fewer after-school activities.	(1) SC bias non-ambiguous (2) SC bias ambiguous Did George say the children should do fewer activities after school? (yes)
	Context biasing DO	**add#1** (make an addition (to); join or combine or unite with others; increase the quality, quantity, size or scope of)
	James showed his wife the list of children going on the school basketball trip and asked her for a pen.	(3) DO bias non-ambiguous (4) DO bias ambiguous Did James think the children should

	(3) He added that **the children were probably better off** joining the trip than spending the holidays at home. (4) He added **the children were probably better off** joining the trip than spending the holidays at home.	spend the holidays at home? (no)
bet	Context biasing SC	**bet#1**, wager#2 (maintain with or as if with a bet
	Tim was deeply depressed about the damage to his brand new Rolls Royce. (1) He bet that **his car was going to be worth** much less than it used to be. (2) He bet **his car was going to be worth** much less than it used to be.	(1) SC bias non-ambiguous (2) SC bias ambiguous Did Tim think his car had kept its value? (no)
	Context biasing DO	**bet#2**, wager#1, play#30 (stake on the outcome of an issue)
	Jeff likes gambling and this time he took a big risk when playing poker. (3) He bet that **his car was going to be worth** enough to let him stay in the game and win back his money. (4) He bet **his car was going to be worth** enough to let him stay in the game and win back his money.	(3) DO bias non-ambiguous (4) DO bias ambiguous Did Jeff think his car was worth enough to stay in the game? (yes)
claim	Context biasing SC	**claim#1** (assert or affirm strongly; state to be true or existing)
	Phil wrote a letter to thank people for being awarded the peace medal. (1) He claimed that **the honour made him very happy** and was the best thing that ever happened to him. (2) He claimed **the honour made him very happy** and was the best thing that ever happened to him.	(1) SC bias non-ambiguous (2) SC bias ambiguous Did Phil say the honor made him very happy? (yes)
	Context biasing DO	**claim#2**, lay claim#1, arrogate#1 (demand as being one's due or property; assert one's right or title to)
	After he won the competition John went down to the awards center.	(3) DO bias non-ambiguous (4) DO bias ambiguous

	(3) He claimed that **the honor made him very happy** and was the best thing that ever happened to him. (4) He claimed **the honor made him very happy** and was the best thing that ever happened to him.	Was the honor the worst thing that ever happened to John? (no)
find	Context biasing SC	discover#4, **find#9** (make a discovery), examples: *"She found that he had lied to her"; "The story is false, so far as I can discover"*
	The students hated having to read the textbook on biology because it was boring. (1) They found that **the book was written poorly and** difficult to understand. (2) They found **the book was written poorly and** difficult to understand.	(1) SC bias non-ambiguous (2) SC bias ambiguous Was the book easy to understand? (no)
	Context biasing DO	**find#3**, regain#2 (come upon after searching; find the location of something that was missed or lost)
	Susan and her friends had been searching for the book everywhere, but were successful in the end. (3) They found that **the book was written poorly and** regretted searching for it. (4) They found **the book was written poorly and** regretted searching for it.	(3) DO bias non-ambiguous (4) DO bias ambiguous Was the book written poorly? (yes)
observe	Context biasing SC	**observe#2**, mention#2, remark#1 (m ake mention of)
	Matt wondered why the government continued to win the elections. (1) He observed that **the people were not aware of any** of the corruption. (2) He observed **the people were not aware of any** of the corruption.	(1) SC bias non-ambiguous (2) SC bias ambiguous Did Matt say the people knew about the corruption? (no)
	Context biasing DO	**observe#3** (observe with care or pay close attention to), **observe#4** (watch attentively)
	In his security job, Joe had to keep an eye on everything. (3) He observed that **the people were not aware of any** dangers around them.	(3) DO bias non-ambiguous (4) DO bias ambiguous Did Joe say the people were not aware of the danger? (yes)

	(4) He observed **the people were not aware of any** danger around them.	
project	Context biasing SC	**project#9**, fancy#1, see#4, figure#3,picture#1, image#2 (imagine; conceive of; see in one's mind), examples: *"I can't see him on horseback!"; "I can see what will happen"; "I can see a risk in this strategy"*
	The journalist asked the filmmaker whether he expected the production would be a success. (1) He projected that **the film would be very popular with** teenagers. (2) He projected **the film would be very popular** with teenagers.	(1) SC bias non-ambiguous (2) SC bias ambiguous Did the journalist think the film might be popular? (yes)
	Context biasing DO	**project#4** (project on a screen)
	At the meeting William wanted to show the video he made recently. (3) He projected that **the film would be very popular with** nature lovers. (4) He projected **the film would be very popular with** nature lovers.	(3) DO bias non-ambiguous (4) DO bias ambiguous Did William think nature lovers would dislike the film (no)
recog-nise	Context biasing SC	**recognise#2**, recognise#6, realise#1, realise#5, agnize#1, agnise#1 (be fully aware or cognizant of)
	Gordon had moved in with his old friend, but they argued a lot. (1) After a while he recognised that **his old friend had adopted a different** lifestyle and he should move. (2) After a while he recognised **his old friend had adopted a different** lifestyle and he should move.	(1) SC bias non-ambiguous (2) SC bias ambiguous Did Gordon think living with his friend was working well? (no)
	Context biasing DO	**recognise#3**, recognise#3, distinguish#2, discern#1, pick out#2, make out#1, tell apart#1 (detect with the senses) **recognise#4**, recognise#7 (perceive to be the same)
	When Billy went to the party he did not know any familiar faces. (3) After a while he recognised that **his old friend had adopted a different** look and appeared different.	(3) DO bias non-ambiguous (4) DO bias ambiguous Did Billy think his friend looked different now? (yes)

	(4) After a while he recognised **his old friend had adopted a different** look and appeared different.	
report	Context biasing SC	**report#2** (announce as the result of an investigation or experience or finding), examples: "Dozens of incidents of wife beatings are reported daily in this city"; "The team reported significant advances in their research"
	The news presenter had to take a deep breath before he gave details of the deaths at the school. (1) He reported that **the students were caught by surprise when** the fire started. (2) He reported **the students were caught by surprise when** the fire started.	(1) SC bias non-ambiguous (2) SC bias ambiguous Did the news presenter say the students were surprised by the fire? (yes)
	Context biasing DO	**report#6** (complain about; make a charge against, examples: "I reported her to the supervisor")
	The teacher saw two of the high school students smoking. (3) He reported that **the students were caught by surprise when** he saw them smoking. (4) He reported **the students were caught by surprise when** he saw them smoking.	(3) DO bias non-ambiguous (4) DO bias ambiguous Did the teacher say the students expected to be caught? (no)
reveal	Context biasing SC	**reveal#2**, discover#6, expose#2,divulge#1, break#15, give away#2, let out#2, uncover#3 (make known to the public information that was previously known only to a few people or that was meant to be kept a secret)
	Samuel asked Jessica why she allowed the children to play with his expensive camera. (1) She revealed that **the camera had actually been broken** for a long time. (2) She revealed **the camera had actually been broken** for a long time.	(1) SC bias non-ambiguous (2) SC bias ambiguous Did Jessica say the camera worked fine? (no)
	Context biasing DO	**reveal#1** (make visible)
	Steve finally agreed to show Sam the package he had hidden under the bed.	(3) DO bias non-ambiguous (4) DO bias ambiguous

	(3) He revealed that **the camera had actually been broken** when he got it. (4) He revealed **the camera had actually been broken** when he got it.	Did Steve say the camera was already broken? (yes)

Appendix D. Results from norming studies for individual verbs

Table D.1.
Results for individual verbs Norming study 1 – completions from verbs in context (in %)

	SC-biased context			**DO-biased context**		
verb	**SC sense**	**SC structure**	**DO structure**	**DO sense**	**SC structure**	**DO structure**
acknowledge	100	96	0	94	3	97
add	92	97	3	91	0	100
bet	84	100	0	94	0	97
claim	97	97	0	95	0	100
find	88	34	52	92	0	100
observe	100	100	0	95	0	100
project	91	60	35	89	0	100
recognise	100	100	0	94	0	100
report	100	39	57	100	0	100
reveal	100	94	6	80	0	100
mean	95	82	15	92.45	0.29	100
SD	5.69	25.29	22.10	4.96	0.9	1.2

Table D.2.
Results for individual verbs Norming study 2 – completions from the verb + NP in context (in %)

	SC-biased context			**DO-biased context**		
	SC sense	**SC structure**	**DO structure**	**DO sense**	**SC structure**	**DO structure**
acknowledge	73	100	0	100	33	67
add	84	100	0	84	0	100
bet	97	100	0	100	0	100
claim	90	100	0	90	15	85
find	96	17	4	100	0	100
observe	65	100	0	100	0	100
project	70	86	0	100	0	100
recognise	93	92	8	100	0	92
report	85	83	17	100	0	100
reveal	94	100	0	93	0	100
mean	85	88	3	97	5	94
SD	11.57	25.71	5.63	5.74	10.97	10.88

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