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Success beyond syntax: Implicatures and Broca's Aphasia*

Abstract Individuals with Broca's aphasia often exhibit difficulties in the comprehension of sentences involving some degree of syntactic complexity, for example, sentences involving overt syntactic movement operations (see, amoung others, Thompson et al. 1999, Grodzinsky 2000, Drai & Grodzinsky 2006, Meyer et al. 2012). Recent accounts of such difficulties converge on the assumption that these difficulties arise from an impairment in language processing (see Druks 2016 for a recent review of this literature). One important debate in the literature is whether this processing difficulty is specific to the syntactic domain (Grodzinsky 2006, Friedmann & Gvion 2003, Burkhardt et al. 2008) or is the result of a domain-general impairment (Just & Carpenter 1992, Caplan & Waters 1990, Caplan et al. 2013, Haarmann et al. 1997, Crain et al. 2001, Varkanitsa et al. 2016, Kasselimis 2015). Despite an extensive literature on the processing of syntactic phenomena in Broca's aphasia (see for example Grodzinsky 2000, Piñango 2000, Burkhardt et al. 2008, Choy & Thompson 2010, Meyer et al. 2012, amoung many others), little is known about how individuals with Broca's aphasia perform on complex linguistic phenomena beyond the syntactic domain. We turn to an investigation of the phenomenon of *implicature* in Broca's aphasia, in order to test whether the language processing impairments observed in this population extend to other linguistic domains (Caplan et al. 2007, Varkanitsa et al. 2016, Kasselimis 2015). We report on two experiments comparing the performance of individuals with Broca's aphasia and typical adult controls on classical scalar implicatures (e.g., the inference that *not all of the students passed* from a sentence like "Some of the students passed") and the so-called 'multiplicity inferences' associated with plural nouns (e.g., the inference that *Emily fed more than one giraffe* from a sentence like "Emily fed giraffes"). In both experiments, we find no difference between the performance of individuals with Broca's aphasia and that of typical adults. We discuss the potential (in)compatibility of our results with the general processing account, against alternative assumptions about the processing cost of computing implicatures.

Keywords: Broca's aphasia, sentence processing, implicatures, pragmatics, plurality

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1 Introduction

Individuals with Broca's aphasia exhibit difficulties with structurally complex sentences (Grodzinsky 2000, Piñango 2000), involving, for example, passivization, relatives clauses, object relatives, pronominal resolution, and certain kinds of *wh*-questions (e.g., Schwarz et al. 1987, Schwartz et al. 1980, Grodzinsky 1989, 2000, Drai & Grodzinsky 2006, Hickok & Avrutin 1995, Burkhardt et al. 2008, Choy & Thompson 2010, Meyer et al. 2012).[1] Given the apparently selective nature of the impairment, the traditional view is that comprehension difficulties in Broca's aphasia arise due to an impairment within the syntactic domain and with respect to syntactic operations in particular (Grodzinsky 2006, Friedmann & Gvion 2003, Burkhardt et al. 2008). An alternative explanation is that these individuals suffer from an impairment affecting language processing more generally (Just & Carpenter 1992, Caplan & Waters 1990, Haarmann et al. 1997, Crain et al. 2001, Varkanitsa et al. 2016, Kasselimis 2015). This latter account is supported by emerging evidence of non-linguistic processing impairments in this population (Peristeri et al. 2011, Novick et al. 2005, Kasselimis 2015). In this paper, we provide a novel perspective on this issue by investigating how individuals with Broca's aphasia perform on linguistic phenomena beyond narrow syntactic operations.

More specifically, we extend the experimental scope of investigation to the semantic/pragmatic domain. We focus on two kinds of *inferences*, and the degree to which such inferred meanings are accessible to individuals diagnosed with Broca's aphasia, as compared to typical adults.

A sentence like (1-a) typically gives rise to the inference in (1-b); similarly, the sentence in (2-a) typically implicates (2-b). These are classical examples of scalar implicatures. The second kind of inferred meaning we will focus on is commonly referred to as a multiplicity inference; an example can be found in (3). We will describe these inferences in more detail in the next section.

(1) a. Some of the giraffes have scarves.
    b. ⇝*Not all of the giraffes have scarves* (Direct) scalar implicature

(2) a. Not all of the giraffes have scarves.
    b. ⇝*Some of the giraffes have scarves* (Indirect) scalar implicature

1 We use the term *Broca's aphasia* here to refer to a collection of symptoms associated with damage to the left inferior frontal gyrus. *Agrammatism* is a specific condition that typically co-occurs with Broca's aphasia, but not exclusively so (e.g., Dick et al. 2001). Very briefly, agrammatic Broca's aphasia typically involves a reduction in the ability to produce coherent and complete sentences, as well as a reduced ability to assign meaning to complex syntactic constructions. In this paper, we subsume agrammatism under the label Broca's aphasia, as all of the participants that were included in the study were diagnosed with Broca's aphasia and displayed symptoms of agrammatism.

(3) a. The giraffe has scarves.
b. ⇝*The giraffe has more than one scarf* Multiplicity inference

Semantic-pragmatic inferences provide an ideal test case for evaluating accounts of comprehension breakdown in individuals with Broca's aphasia, as can arise from sentences that are not necessarily complex from a syntactic perspective, but involve complexity at the level of semantic-pragmatic interpretation. Evidence for 'complexity' in this domain comes from research indicating that (at least some) inferences are associated with a processing cost for typical adults (e.g., Bott & Noveck 2004, Huang & Snedeker 2009, Chemla & Bott 2013, Cremers & Chemla 2014). Implicatures also appear to be acquired relatively late by children (see, among many others, Noveck 2001, Gualmini et al. 2001, Papafragou & Musolino 2003). By investigating implicatures in Broca's aphasia, we can determine whether the language processing impairments observed in this population can be generalized beyond the syntactic domain (amoung many others, see Caplan et al. 2007, Varkanitsa et al. 2016, Kasselimis 2015).

The remainder of this paper is organized as follows. In Section 1.1 we will begin by providing a brief overview of the literature on Broca's aphasia. We then provide a more detailed description of scalar implicatures and multiplicity inferences in Section 1.2, including a brief sketch of a theoretical account of such inferences, and an overview of some psycholinguistic experiments that have investigated these inferences. We will then turn to our two experiments in Section 2, designed to measure the computation of implicatures in individuals with Broca's aphasia. In Section 3 we conclude by discussing the implications of our findings for proposals concerning the impairments observed in Broca's aphasia, as well as those concerning the nature and cost of implicatures such as scalar implicatures and multiplicity inferences.

1.1 Broca's aphasia

Individuals diagnosed with Broca's aphasia typically exhibit impairments in processing sentences involving some form of structural complexity. The notion of *processing complexity* has been defined in various ways in the literature, but in the context of Broca's aphasia, it is often used to describe sentences where grammatical operations have resulted in marked (non-canonical) word orders. For example, poor performance has been reported on passive sentences, certain kinds of *wh*-questions, object relative clauses, and object cleft structures (Thompson et al. 1999, Hickok & Avrutin 1995, Grodzinsky 2000). A growing body of work also reveals impaired performance on pronominal and anaphora resolution (e.g., Grodzinsky & Reinhart 1993, Love et al. 1998, Edwards & Varlokosta 2007, Choy & Thompson 2010) however, the findings of this work revealed a mixed picture.

Early debates in the literature on Broca's aphasia centered around the underlying source of the grammatical impairments observed in this population, with explanations ranging from a loss of syntactic knowledge (Grodzinsky 2000) to a reduction in language processing resources more generally (Just & Carpenter 1992, Caplan & Waters 1990, Haarmann et al. 1997, Crain et al. 2001, Varkanitsa et al. 2016, Kasselimis 2015). Independent evidence from the online processing of more basic sentences also indicates delayed lexical access, as well as delayed priming effects in this population (Swinney et al. 1996, Love et al. 2008). These findings have been explained with reference to a slow down in syntactic processing (e.g., Piñango 2000, Burkhardt et al. 2008). In addition to linguistic deficits, there is also emerging evidence for non-linguistic cognitive deficits in this population, for example involving working memory (Varkanitsa et al. 2016, Kasselimis 2015), cognitive control (Novick et al. 2005), inhibition (Peristeri et al. 2011), and impairments in non-verbal reasoning and problem solving (e.g., Baldo et al. 2005, 2010). In sum, the emerging picture from studies of individuals with Broca's aphasia suggests limitations in both language and cognitive functioning (e.g., Yarbay Duman et al. 2016).

While it is now generally acknowledged that individuals with Broca's aphasia suffer from some sort of processing limitation, the exact nature of the limitation, and its role in explaining comprehension performance in this population remains controversial.[2] One camp argues that syntactic processing is selectively impaired (e.g., Grodzinsky 2006, Friedmann & Gvion 2003, Burkhardt et al. 2008), while the other maintains the limitation lies in a general reduction in processing resources (e.g., Caplan & Hildebrandt 1988, Dick et al. 2001, Bates et al. 1991, Just & Carpenter 1992; see also Caplan et al. 2013 for a recent review of resource reduction accounts). The two approaches lead to different expectations regarding non-syntactic linguistic performance. On the one hand, syntax-specific accounts do not make any clear predictions for phenomena beyond syntax. A finding of impaired performance on pragmatic inferences, however, might be surprising on a purely syntactic account of the observed limitations. On the other hand, a general reduction approach predicts that phenomena that are difficult to process for typical adults might lead to additional challenges in individuals with Broca's aphasia, such that their performance should diverge from that of typical adults. Investigating the performance of this population on linguistic phenomena beyond the syntactic domain is therefore a necessary extension to the existing research on Broca's aphasia.

In contrast to the relatively large body of existing research on syntactic processing, little is known about how individuals with Broca's aphasia engage with the sort of semantic/pragmatic inferences that are the focus of the present study.

2 See Druks (2016) and Bastiaanse & Thompson (2013) for recent reviews of traditional and contemporary theories of aphasic performance.

Existing work has typically considered pragmatics in terms of social function or communication skills. In this domain, research suggests that individuals with Broca's aphasia are generally pragmatically competent (e.g., Dronkers et al. 1998, Wulfeck et al. 1989).[3]

In one study of non-syntactic phenomena in Broca's aphasia, Yarbay Duman et al. (2016) tested a group of individuals with Broca's aphasia on their comprehension of counterfactual conditionals such as *If he had ironed the shirt, he would have hung it in the closet*. The data are relevant to the current study because, as we will discuss in the next subsection, computing an implicature requires a form of counterfactual reasoning. In simple terms, the hearer must consider alternative sentences that the speaker could have uttered but chose not to. In fact, counterfactual reasoning has been implicated as a potential source of the processing complexity associated with scalar implicatures (Van Tiel & Shaeken 2016). Yarbay Duman et al. (2016) reported that a group of Turkish-speaking individuals with Broca's aphasia displayed impaired processing of counterfactuals, compared to performance on indicative conditional counterparts. This finding is relevant for our purposes, as the processing of counterfactuals has been argued to involve a number of steps that are similar to those involved in computing implicatures, specifically: ignoring the actual outcome, maintaining both factual and counterfactual representations in working/short term memory, and finally, selecting between the two interpretations (e.g., Beck et al. 2009). Given these findings, we would expect that individuals with Broca's aphasia will also struggle with the inferences tested in the current study, namely scalar implicatures and multiplicity inferences. We introduce these inferences in the next section.

1.2 Scalar Implicatures

The term 'scalar implicature' refers to the notion that certain expressions or lexical items are arranged in terms of a 'scale' of strength or informativeness (Horn 1972). The alternatives for a given expression are other expressions along the same scale, referred to as 'scale mates.' A scalar implicature arises when a weak scalar term is used in a context where a stronger alternative would be relevant. This in turn leads to the negation of the stronger alternative(s). To illustrate briefly, a sentence such as

3 One cross-linguistic study by Wulfeck et al. (1989) focused on the use of pragmatic reference by individuals with Broca's aphasia, in particular, the use of lexical items signalling newness and givenness in language production. The findings indicated that the Broca's aphasia group (as well as a group of individuals with Wernicke's aphasia) showed preserved abilities in using pragmatic reference. Further, a priming study by Nakano & Blumstein (2004) indicates that individuals with Broca's aphasia can use pragmatic information when assigning thematic roles during sentence processing.

(4-a) containing the weak scalar term *some* results in the negation of the stronger alternative *all*, (4-b), giving rise to the inference in (4-c).

(4) a. Some of the giraffes have scarves.
b. All of the giraffes have scarves.
c. ↪*Some but not all of the giraffes have scarves*

A traditional approach to these inferences is to posit that they arise via a process of pragmatic reasoning about speaker intentions (e.g. Grice 1975, Horn 1972). Roughly speaking, a speaker uttering a sentence with the weak scalar term *some*, as in (5-a), invites the hearer to infer that the speaker could not truthfully utter the more informative (and relevant) (5-b) with the logically *stronger* scalar alternative *all*.[4] This in turn leads to an interpretation of (5-a) as (5-c).

A sentence like (4-a) can therefore be associated with two potential readings: the literal reading in (4-a), which is compatible with the stronger alternative in (4-b), and the inference reading in (4-c) that involves the negation of the stronger alternative (4-b). A similar process is assumed to apply to strong scalar items like *all* under negation: a speaker uttering (5-a) instead of the relevant and more informative (5-b) leads the hearer to infer that (5-b) is false, resulting in the interpretation in (5-c).

(5) a. Not all of the giraffes have scarves.
b. It is not that case that some of the giraffes have scarves.
(≈ none of the giraffes have scarves)
c. ↪*Not all of the giraffes have scarves, but some of them do*

While treated uniformly, the cases of (4-b) and (5-b) are sometimes referred to as a Direct Scalar Implicature (DSI) and Indirect Scalar Implicature (ISI), respectively.[5] We will adopt this terminology here.[6] In the case of *some*, the inference in (5-c) is not obligatory; for instance, we can force a reading without the inference by adding to (5-a) the continuation: ... *in fact, none of them did*. The optionality of the

4 The concept of 'strength' here is defined in terms of logical strength, whereby a less specific expression refers to one which is less informative than a salient (stronger) alternative. To provide a brief example, the expression *all* is stronger than the alternative *some* because in any situation where *all* is true, *some* must also be true. The reverse, however, does not hold. This is referred to as an 'asymmetric entailment' relation and allows us to plot expressions like *all* and *some* along a scale based on their relative strength (e.g., Horn 1972).

5 Although the mechanism underlying DSIs and ISIs is the same, the difference is that a DSI arises when a weak scalar term is used in an upward-entailing (positive) context where a stronger alternative would be relevant, while an ISI arises when a strong scalar term is used in a downward-entailing (negative) context, e.g., *not all*.

6 Other scalar implicatures assumed to arise via a similar mechanism include numeral expressions and plural morphology.

implicatures in (4-c) and (5-c) is a hallmark of scalar implicatures more generally. We will return to this point in Section 1.3 below.

Traditional pragmatic theories (e.g., Grice 1975, 1989, Horn 1972) are also referred to as 'counterfactual theories' (e.g. Van Tiel & Shaeken 2016), as they require a speaker to reason over alternative events or outcomes. Under this approach, scalar implicatures are derived from reasoning about speaker intentions in light of basic assumptions about co-operative communication: co-operative speakers generally aim to make maximally informative, relevant, and true statements (see, e.g., Grice 1975, Sauerland 2004, and much subsequent work).[7]

It is generally agreed that the computation of a scalar implicature involves at least the following steps: the decision to compute the inference, the generation of relevant alternatives, and the negation of relevant alternatives (cf. Barner et al. 2011, Marty & Chemla 2013, Chemla & Singh 2014). What is relevant for our purposes is that, given the various stages of computation, the derivation of scalar implicatures arguably involves some level of 'complexity'. [8]

Scalar implicatures like those in (4) and (5) have been the subject of a substantial body of experimental research (e.g., Reinhart & Siloni 2004, Pouscoulous et al. 2007, Katsos & Cummins 2010, Chemla & Singh 2014), from both a processing and a developmental perspective. The general thrust of much of this work is that scalar implicatures are both processed slowly by adults and acquired later by children (see, e.g., Noveck 2001, 2004). Taken together, such findings appear to indicate that the derivation of an implicature carries a processing cost. In particular, one line of work suggests that this cognitive cost taxes memory resources (e.g. Marty et al. 2013, De Neys & Shaeken 2007). While typical adults generally tend to judge sentences such as (5) based on an interpretation that includes the implicature (5-c), existing processing evidence appears to indicate that these interpretations are nonetheless associated with a processing cost. This has been supported by both reaction times (e.g., Bott & Noveck 2004) and eye-tracking data (Huang & Snedeker 2009, Chemla & Bott 2013, Cremers & Chemla 2014), which indicate behavioral delays for implicature interpretations relative to literal interpretations. While the exact source of the delays is still unclear, a number of possible candidate explanations have been proposed, including costs associated with the generation or comparison

7 Scalar implicatures have traditionally been considered to arise from principles of rational interactions (Grice 1975, 1989); however, some more recent accounts derive implicatures through grammatical mechanisms (e.g., Fox 2007, Chierchia et al. in press). Despite inherent conceptual differences, both the traditional pragmatic approaches and the grammatical approaches assume an interactive mechanism of implicature computation that relies on input from both grammar (syntax/semantics) and pragmatics (see Chemla & Singh 2014 for discussion).

8 It is worth pointing out, however, that the exact relationship between the derivation of implicatures and the actual psycholinguistic processing signature of implicatures is far from clear (see Chemla & Bott 2013 and Chemla & Singh 2014 for discussion of this point).

of alternatives, the use of contextual information in deciding which alternatives are relevant, and the complexity of the sentence meaning with and without the inference (Chemla 2009, Chemla & Bott 2013).[9]

Importantly, some recent research has questioned whether scalar implicatures are in fact associated with a delay at all (e.g., Grodner et al. 2010, Breheny et al. 2013, Schwarz 2015). For example, in a study using the visual world eye-tracking paradigm, Grodner et al. (2010) found that the implicature associated with *some* is computed immediately and not delayed relative to the literal meaning, running counter to the findings reported in Bott & Noveck (2004) and Huang & Snedeker (2009). We will return this point in section 3.

Further evidence that scalar implicatures may be complex to process comes from the acquisition literature. One robust finding from this body of work is that while adults tend to respond to sentences like (4), repeated below in (6), in a manner consistent with having computed the implicature in (6-b), children tend to respond in a manner consistent with accessing the literal meaning in (6-a) (Gualmini et al. 2001, Papafragou & Musolino 2003, Musolino & Lidz 2006, Katsos & Cummins 2010).[10]

(6) Some of the giraffes have scarves
   a. Some (or all) of the giraffes have scarves.
   b. $\hookrightarrow$ *Not all of the giraffes have scarves*

One account of children's tendency to accept underinformative statements is framed in terms of the processing cost associated with computing implicatures, consistent with the processing literature from typical adults. For example, Pouscoulous et al. (2007) and Reinhart (2004) propose that children display lower rates of implicatures because, up to a certain stage of development, they lack the required processing resources to execute one or more of the steps involved in generating implicatures. For instance, Pouscoulous et al. (2007) reports that children are more likely to reject underinformative statements when the processing demands of the task are simplified.

While the psycholinguistic literature on the processing of scalar implicatures reveals a mixed picture, what is relevant for our purposes is that one or more processes involved in deriving such inferences are associated with extra cognitive effort, compared to accessing literal meanings. In light of these findings, the present study was designed to directly assess the relation between the apparent processing

9 For example, a study by Marty & Chemla (2013) suggests that the cost of deriving implicatures is not simply related to the additional semantic complexity of sentences enriched with their scalar inference, but rather to the initial step of deciding whether or not to compute the implicature.

10 Most of this work has focused on direct scalar implicatures such as (6-b). Less research has focused on indirect scalar implicatures, but there is some existing work that suggests parallels between DSIs and ISIs, e.g., Musolino & Lidz 2006, Katsos & Cummins 2010, Cremers & Chemla 2014).

limitations in Broca's aphasia and these previous findings.

Before moving on to describe the current experiment, we will describe one previous experiment that formed the basis of our own study investigating scalar implicatures. Bill et al. (2016) tested a group of 20 typical adults and two groups of children (sixteen 4–5-year-olds, fourteen 7-year-olds) on scalar implicatures and presuppositions using a version of the sentence-to-picture matching task known as the Covered Box paradigm (e.g., Huang 2013, Romoli 2014).[11] The main aim of the study was to evaluate the predictions of a recent unified approach that sees (certain) presuppositions as a type of scalar implicature (Abusch 2010, Chemla 2010, Romoli 2014). Participants were shown a context picture and two test pictures for each trial, one visible and one covered. To 'set the scene' and to ensure felicity in accordance with the 'condition of plausible dissent' (Crain et al. 1996), the experimenter produced a short description of the context picture followed by a test sentence that described just one of the two pictures, either the visible or the covered. The participant's task was to decide for each test sentence whether it described the visible or the covered picture. Crucially, on the test trials, the visible picture was consistent only with the literal meaning of the sentence. For example, a participant would hear (7) below, accompanied by a visible picture in which all of the lions had balloons. The selection of the visible picture therefore indicated that the participant's response was based on an interpretation of the sentence without the relevant inference. Selection of the covered picture, on the other hand, indicated that the participants were accessing the scalar implicature.

(7) Some of the lions have balloons.

The results indicated that the rate of covered box choices (corresponding to computation of the inference) differed by group and by type of inference. Consistent with previous findings, children tended to respond based on a literal interpretation of the test sentences, while adults displayed the opposite pattern.[12]

Before moving on to our experiment, we next turn to a brief outline of multiplicity inferences, including a previous study that has compared scalar implicatures and multiplicity inferences in children and adults.

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11 This paradigm is somewhat similar to the traditional Truth Value Judgement Task (Crain & Thornton 1998); however, it differs in certain important ways. One difference is that by having an 'unknown' option (the covered picture), participants must actively consider alternative interpretations of the sentence. A further difference and potential advantage of this paradigm is that the chances of participants accepting the test sentences due to other factors, e.g., politeness or confusion, are reduced.

12 Recall that Bill et al.'s (2016) study compared scalar implicatures and presuppositions (e.g., the inference that *Bear participated* from a sentence like *Bear didn't win*) in order to test the predictions of unified analyses of the two kinds of inferences. Bill et al.'s results indicated children and adults treated the two inferences differently, thus challenging the unified accounts.

1.3 Multiplicity inferences

The distinction between the plural and the singular has been the subject of long-standing debate in the linguistics literature. Plural bare nouns such as *apples* in (8-a) are often used to refer to more than one set of objects; that is, plural morphology in (8-a) appears to trigger the meaning in (8-b), namely that Sue picked more than one apple. Such examples were behind the traditional assumption that the *more than one* meaning was inherent to the semantics of the plural (e.g., Link 1983, Lasersohn 1995, Chierchia 1998).

(8) a. Sue picked apples.
    b. $\hookrightarrow$ *Sue picked more than one apple*

A major challenge to this view comes from the observation that there are contexts in which plural morphology is not used to refer to more than one object. This is illustrated in the negative sentence in (9-a) below. In this case, the plural sentence in (9-a) is associated with the negation of the singular in (9-c) (that Sue didn't pick a single apple), rather than the negation of the plural, as in (9-b). Yet (9-b) is what would be expected under the traditional view on which plural morphology lexically encodes a multiplicity reading (e.g., Lasersohn 1995).

(9) a. Sue didn't pick apples.
    b. $\hookrightarrow$ *Sue didn't pick more than one apple*
    c. $\hookrightarrow$ *Sue didn't pick a single apple*

In other words, the multiplicity reading of the plural appears to disappear under negation and in fact in downward-entailing contexts more generally. In response to this puzzle, some researchers have argued that there is nothing within the semantics of the plural that constrains its meaning to referring to more than one object (e.g., Magri 2010, Thomas 2012, Abusch 2010, Chemla 2010, Romoli 2014). Rather, on these alternative approaches, the multiplicity reading arises as a type of implicature.

In fact, a recent approach in the literature on semantic-pragmatic inferences has involved attempts to analyze a variety of traditionally distinct phenomena under the umbrella of scalar implicatures (see for example, Magri 2010, Thomas 2012, Abusch 2010, Chemla 2010, Romoli 2014). Multiplicity inferences are but one example of an inference that arises in upward-entailing contexts but disappears in downward-entailing contexts (Sauerland et al. 2005, Spector 2007, Zweig 2009, Ivlieva 2013, Magri 2014), with disappearance in downward-entailing contexts a hallmark of scalar implicatures. Disjunction for example, is standardly understood exclusively in upward-entailing contexts (10), i.e. as conveying that only one of the disjuncts is true; yet under negation *or* is understood inclusively, i.e., (11-b) is incompatible not only with Sue having picked one or the other type of fruit, but also with her having picked both types of fruits. This sensitivity to monotonicity is exactly parallel to what we have observed for the plural.

(10) Sue picked apples or oranges.

(11) a. Sue didn't pick apples or oranges.
b. ↝*Sue didn't pick apples and she didn't pick oranges*

This parallel has led to the hypothesis that the multiplicity reading of sentences containing plurals arises as a type of scalar implicature (Sauerland et al. 2005, Spector 2007, Zweig 2009, Ivlieva 2013, Magri 2014). Under this theory, the 'more than one' reading of plural sentences is not encoded in the lexical entry for the semantics of the plural. Following Spector (2007) and Magri (2014), the plural (12-a) and the singular (12-b) overlap in their semantics, in that the singular is included in the semantics of the plural, as paraphrased in (12-c). How then is the multiplicity inference in (12-d) derived?

(12) a. Sammy painted birds.
b. Sammy painted exactly one bird.
c. Sammy painted *one or more* birds.
d. ↝*Sammy painted more than one bird.*

(12-d) is assumed to arrive via implicature. One way of capturing this is to posit that the plural in (12-a), which has the literal meaning in (12-c), gets compared to the stronger singular in (12-b). Under the traditional Gricean reasoning, the listener would infer that as the speaker did not use the stronger (12-b), she must not believe it to be true. The negation of the stronger singular alternative then triggers the multiplicity inference in (12-d).

One advantage of this implicature approach to the multiplicity inference is that it can successfully account for the behavior of plural morphology in downward-entailing contexts. The implicature approach can also successfully account for a second property of multiplicity inferences, namely the existence of a marked 'more than one' meaning of the plural that can be forced in downward-entailing contexts, as in (13). The optionality of plural reading in (12-d) is again reminiscent of some other implicatures we have seen.

(13) Sue didn't pick apples, she only picked one!

One prediction of the implicature account, as it aligns multiplicity inferences with other implicatures, is that the acquisition profile of multiplicity inferences should mirror that of other scalar implicatures. More specifically, we might expect children to access multiplicity inferences at a lower rate than adults, just as they seem to compute fewer standard implicatures than adults do. This prediction appears to be borne out in the acquisition literature (Sauerland et al. 2005, Tieu et al. 2014, 2017).

In a recent study, Tieu et al. (2014, 2017) investigated the predictions of the implicature account by investigating multiplicity inferences and scalar implicatures in adults and 4–5-year-old children, using a Truth Value Judgment Task (Crain & Thornton 1998). In their first experiment, they tested plural and singular sentences in both upward-entailing and downward-entailing contexts; in their second experiment the researchers directly compared performance on multiplicity inferences and the scalar implicature of *some* (e.g., (14)-(15)). Crucially, the plural sentences were presented in contexts in which the main character had acted on only one object from a set of objects, hence falsifying the multiplicity inference. The scalar implicature target sentences were likewise presented in contexts that falsified the *not all* implicature.

(14) Plural target
Context: Zebra picked exactly one banana.
Sentence: Zebra picked bananas.

(15) Scalar implicature target
Context: The lion carried all of the apples.
Sentence: The lion carried some of the apples.

The results of Tieu et al.'s experiments revealed that children generally computed fewer of both kinds of inferences than adults did, consistent with the general acquisition profile of classical scalar implicatures. Moreover, the second experiment, which used a within-subject design to compare plural sentences containing *some* sentences, revealed that children's performance on the two kinds of inferences was strongly correlated. The overall findings suggest that similar or parallel underlying mechanisms are involved in the computation of scalar implicatures and multiplicity inferences, consistent with the uniformity predictions of the implicature approach to plurals (e.g., Sauerland et al. 2005).

1.4 Summary and motivations

Against the background that we have just reviewed, there are two main motivations underlying the present study in which we compare the performance of typical adults with the same group of individuals with Broca's aphasia tested in experiment one, on plural sentences in both upward entailing and downward entailing contexts. The first aim is to contribute to the proper characterization of language processing impairments in Broca's aphasia. The second is to contribute to the emerging body of theoretical and experimental work that seeks to analyze multiplicity inferences under the umbrella of scalar implicature.

Scalar implicatures arguably involve some level of semantic-pragmatic 'complexity' required to implement the various steps involved in computing implicatures. This conjecture is supported by work from typical adult processing studies indicating a cost associated with accessing scalar inferences compared to literal meanings (e.g., Bott & Noveck 2004, Huang & Snedeker 2009, Chemla & Bott 2013, Cremers & Chemla 2014, Marty & Chemla 2013), and by the observation that young children tend to access literal interpretations more often than scalar implicatures.

Turning to Broca's aphasia, while there is a body of literature in the area of syntactic processing in this domain, little is known about how this population engages with non-syntactic phenomena that are likewise associated with a processing cost. By moving beyond syntax we can refine the picture of what is spared and retained in this disorder. More specifically, we aim to contribute to the debate of whether the processing impairments shown by this population is specific to syntactic processing or rather reflects a reduction in processing resources more generally. Interestingly, these two approaches lead to different expectations regarding the performance of individuals with Broca's aphasia on complex phenomena outside of syntax. While syntax-specific accounts do not make any clear predictions for non-syntactic phenomena, a finding of impaired performance on implicatures may suggest that this type of account cannot be maintained without further assumptions. Assuming a general reduction in resources, however, one might expect that a phenomenon that presents a processing challenge for neurotypical adults should also be challenging, if not more challenging, for individuals with Broca's aphasia.

Finally, in relation to the theoretical analysis of multiplicity inferences, recent approaches make a uniformity prediction regarding performance on multiplicity inferences and scalar implicatures. Recent work in acquisition suggests that this approach may be on the right track (e.g., Sauerland et al. 2005, Tieu et al. 2014, 2017). We add to this work by testing the uniformity prediction on a further population.

2 Experiments

Two of the studies we have discussed (Bill et al. 2016 and Tieu et al. 2017) adopted a comparative approach to the semantic-pragmatic inferences they tested, with the main aim of investigating whether two types of inferences should receive a unified analysis. In particular, Bill et al. (2016) focused on the comparison between scalar implicatures and presuppositions, while Tieu et al. (2017) examined the comparison between multiplicity inferences and scalar implicatures. Experiments in both the language acquisition and aphasia literature typically employ similar experimental paradigms, with sentence-to-picture matching and Truth Value Judgement Tasks representing two of the most commonly used paradigms. Therefore these studies provide a perfect foundation for investigating our own questions regarding language and processing in Broca's aphasia. We will use the same paradigms as those reported in Bill et al. (2016) and Tieu et al. (2017) to compare the performance of typical adults and individuals with Broca's aphasia on scalar implicatures and multiplicity inferences.

In Experiment 1, we focus on classical scalar implicatures arising from *some* and *not all*; as we will see, the Broca's aphasia group do not differ from typical adults on these inferences.[13] In Experiment 2 we focus on multiplicity inferences, and again find parallel performance in our two groups. The results of our experiments indicate that individuals with Broca's aphasia can successfully access both traditional scalar implicatures and multiplicity inferences.

2.1 Experiment 1

2.1.1 Participants

Nine individuals diagnosed with Broca's aphasia (age 48-63 years, M=53.4, time post onset 1.4-9 years, M=5.6) took part in the study. We compared their performance to that of the 22 typical adults reported on in Bill et al. (2016). The typical adults were all university undergraduates at Macquarie University and had no history of cognitive or neurological impairment. The participants with Broca's aphasia were recruited from local Stroke Association Communication groups. All individuals with Broca's aphasia were right-handed, had suffered a single left-sided cerebrovascular accident (CVA), and were at least one year post-stroke onset. A summary of participant demographic and clinical information is provided in Table 1.

Diagnosis with agrammatic Broca's aphasia was made on the basis of general lesion location (left sided) and behavioural testing. In particular we used several criteria: (i) assessment by an experienced clinical Speech and Language therapist, (ii) performance on the Western Aphasia Battery (WAB, Kertesz 1982), and (iii) performance on non-canonical sentences (passives and object clefts) on the Verb and Sentence Test (VAST, Bastiaanse et al. 2003). Participants were tested on the first section of the WAB in which participants are tested on spontaneous speech (information content and speech fluency), auditory comprehension, repetition, naming, and word finding. These tests allowed us to calculate an aphasia quotient (AQ) for each participant indicating the severity of aphasia (Kertesz 1982). WAB AQ scores ranged from 28.2 (severe aphasia) to 59.6 (moderate aphasia), with a mean of 49.2.[14]

13 Kennedy et al. (2015) also compared direct and indirect scalar implicatures to presuppositions. We leave aside this comparison for the present paper.

14 An AQ below 93.8 indicates aphasia (see, e.g., Kertesz 1982, Pederson et al. 2004). Based on

Study ID	Sex	Age	TPO	Aetiology	Handedness
A1	M	63	9	Left CVA	Right
A2	M	56	4	Left CVA	Right
A3	F	32	2	Left CVA	Right
A4	M	62	1.4	Left CVA	Right
A5	M	55	9	Left CVA	Right
A6	M	59	9	Left CVA	Right
A7	F	63	2	Left CVA	Right
A8	M	48	4	Left CVA	Right
A9	M	53	3	Left CVA	Right

Table 1 Table 1: Demographic and lesion information for participants with Broca's aphasia.

Individual results from the WAB and the VAST are provided in the appendix. All of the participants with Broca's aphasia who were included in this study showed generally better performance on canonical (active and subject clefts) than non-canonical sentences (passives and object relatives).[15]

2.1.2 Procedure

The materials and procedure used in this study were identical to those employed by Bill et al. (2016) described in Section 1.2. Prior to the test phase, all participants underwent a short training session to ensure they understood the task. Following this, participants were presented with test trials each consisting of three pictures: one context picture and two test pictures. Pictures were presented on a large poster with the context picture at the top centre of the poster and the two test pictures underneath. One of the test pictures was visible (uncovered), while the other was covered, i.e. represented as a black box. Crucially, participants were told that only one of the test pictures was visible and the other was a black box (covered picture).

the aphasia quotients, 11 participants suffered from moderate aphasia (AQ=31.3-62.5) and one participant had severe aphasia (AQ=0-31.2). Most of the participants with aphasia also suffered from concomitant motor speech disturbances such as dysarthria and dyspraxia. These impairments are typically associated with a diagnosis of Broca's aphasia.

15 One participant (A7) showed uniform performance across subject and object clefts and passive sentences but better performance on active sentences. Of note, this is the one participant who presents with severe aphasia, hence it is possible that the low scores on subject cleft sentences are related to the relative complexity of these sentences compared to simple actives.

The researcher then told a short story to set the context for the pictures, and then presented the test sentence, at which point participants were asked to point to the picture (visible or covered) that they thought the sentence referred to. An example of a *some* target trial is provided in (16), and the corresponding test pictures are provided in Figure 1.[16]

(16) ‘Today, a group of pigs and a group of giraffes went out in the rain. None of the pigs wore scarves. But, some of the giraffes wore scarves. So remember, **some of the giraffes wore scarves**.’
Visible picture: All of the giraffes wore scarves

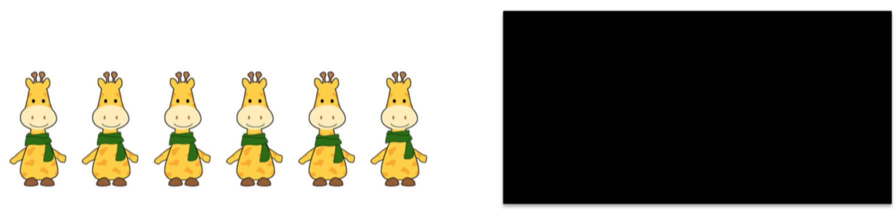


Figure 1 Visible vs. covered picture for a *some* test trial, accompanying the story and sentence in (16).

2.1.3 Materials

On the critical test trials, the visible picture was consistent only with the literal meaning of the sentence. Selection of the visible picture therefore indicated that participants were responding based on the literal meaning of the sentence, e.g., as in (17-a), while selection of the covered picture indicated that participants were responding based on the inference reading, e.g., (17-b).

(17) Some of the giraffes have scarves.

16 As far as we are aware, the Covered Box paradigm has not previously been used with individuals with Broca’s aphasia. However, sentence-to-picture matching tasks are one of the most common methods of testing sentence comprehension in this population. The inclusion of control trials as well as the training phase of the experiment allowed us to ensure that all participants with Broca’s aphasia understood the task and could respond accurately in the relevant contexts.

a. *Some or all* of the giraffes have scarves.
b. *Some but not all* of the giraffes have scarves.

In total, participants received a total of 4 DSI and 4 ISI target trials.[17] Figure 2 shows an example of a visible picture on an ISI target trial, and Figure 3 provides an example of a visible picture on a DSI target trial.

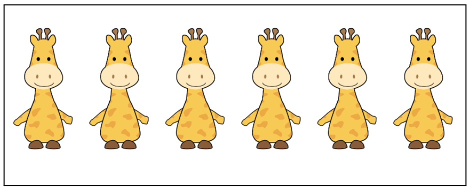


Figure 2 Example of a visible picture on an ISI (*not all*) target trial.

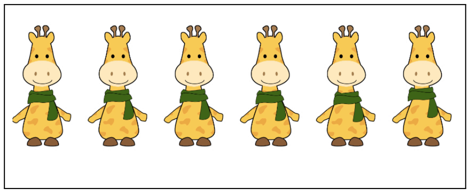


Figure 3 Example of a visible picture on a DSI (*some*) target trial.

Participants also received 12 control trials, six in which the test sentence was consistent with the visible picture and six where it was inconsistent with the visible picture and thus was expected to elicit a covered picture selection. (18) illustrates a *some* control where the visible picture is consistent with the test sentence. (19) illustrates a *not all* control where the visible picture is inconsistent with the test sentence, hence participants were expected to select the covered picture.

(18) Visible picture *some* control
Visible picture: 2 of the 5 elephants have a tennis racquet
Sentence: Some elephants have a tennis racquet.

(19) Covered picture *not all* control
Visible picture: All cats have an ice cream
Sentence: Not all cats have an ice cream.

17 Participants were also tested on presuppositions, but we only present here the relevant data pertaining to implicatures; see Bill et al. 2016 for details regarding the presupposition data.

These controls ensured that participants could correctly select the visible and covered pictures in appropriate contexts.[18] Only participants who responded correctly to at least 3 out of the 4 controls per condition were included in the analysis.

2.1.4 Results and discussion

The typical adult group selected the covered picture on the critical implicature targets 71.88% of the time (SE = 8.83), while the aphasic group selected the covered picture 73.61% of the time (SE = 11.87). Recall that covered box selection indicated that participants were accessing the inference reading of the target sentences. Both groups selected the covered picture on target trials more often than the visible picture, indicating a higher rate of responses based on the inference readings of the target sentences than literal readings.

A non-parametric Mann-Whitney test revealed no significant difference between the two groups (Wilcoxon-Mann-Whitney $W = 92, p = .93$). This result indicates that the Broca's aphasia group successfully accessed readings of the target sentences that included their scalar implicature. There are two potential hypotheses we could explore in relation to these results. The first hypothesis is that the processes underlying scalar implicature computation are spared in Broca's aphasia. This finding is surprising given research indicating that one or more of these mechanisms is associated with a processing cost. Such a finding would be unexpected under an account of Broca's aphasia that attributes linguistic deficits to a general reduction in processing resources. A second potential hypothesis to explore is that, consistent with some emerging experimental literature, scalar implicatures are not (as) costly as previous work would suggest. Under the second hypothesis, a general resource reduction account could, in theory, be maintained. We will explore these hypotheses in more detail in Section 3.1.

Before discussing these results further, we will move on to a second experiment conducted with the same group of individuals with Broca's aphasia, this time focusing on multiplicity inferences.

2.2 Experiment 2

We turn now to an experiment that extends the investigation in Experiment 1 to multiplicity inferences. We have shown above that multiplicity readings also arise as a type of implicature an that the implicature account of multiplicity inferences

18 Crucially, the visible picture controls were only presented after all the critical trials for the relevant condition had been presented. This was done to ensure that participants were not exposed to a picture suggesting an interpretation consistent with the relevant inference until after they had given all their judgments for the relevant critical trials.

makes a uniformity prediction that has already found some support from existing experimental work in acquisition (e.g., Sauerland et al. 2005, Tieu et al. 2014, 2017). We extend this line of research here by evaluating the uniformity prediction in a group of individuals with Broca's aphasia. Given the results from Experiment 1, which indicate that these individuals can successfully compute scalar implicatures, the implicature account of multiplicity inferences predicts that they should also be able to compute multiplicity inferences.

2.2.1 Participants

The participants with Broca's aphasia from Experiment 1 also participated in Experiment 2. We compare their data here with that of the typical adult controls reported on in Tieu et al. (2017).

2.2.2 Procedure

We employed the same methods and materials as those reported in Tieu et al. (2017) (described briefly in Section 1.3). Participants watched a series of short stories told by an experimenter, using pictures on a laptop computer. Participants were introduced to a recorded individual who would answer questions about the stories presented by the researcher.[19,20] At the end of each story, the recorded individual was asked a question about the story, and the participant was instructed to judge whether the answer was right or wrong, given the context shown on the laptop. Typical adult controls gave their answers verbally while participants with aphasia indicated their responses by pointing to either a happy face or a sad face. This was to circumvent any potential issues with obtaining accurate verbal responses from aphasic participants, and to reduce the task demands. The task lasted around 10-15 minutes for typical adults and 20-30 minutes for the aphasic participants.

2.2.3 Materials

We employed the same stories and visual stimuli as those in Tieu et al. (2017). Participants received a total of 14 trials, including six target trials (three plural sentences in upward-entailing contexts and three in down-entailing contexts) and

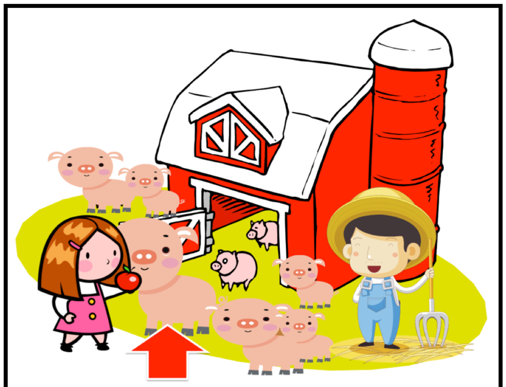
19 The Tieu et al. 2017 study used videos of a puppet rather than videos of one of the researchers, for the purposes of engaging with the child participants. Here, we replaced the puppet videos with videos of one of the researchers, so as to avoid any possibility that the adult participants with aphasia might feel they were being patronized.

20 As the data for the adult participants are taken from the Tieu et al. (2017) study, they were tested using the puppet paradigm.

eight control trials (two positive and two negative plural controls and four negation controls). Items were randomized using random number tables and presented in a pseudo-randomized order.

In the upward-entailing condition, the main character in the story executed an action on only one object from a set of objects. Participants then heard a (pre-recorded) test sentence containing a bare plural, such as *Emily fed pigs!* Example (20) provides a sample test item and Figure 4 displays the image corresponding to the outcome of the story in (20).

(20) Story: Emily is visiting the pig farm today. It's lunchtime for the pigs. Emily has an apple, and that's just enough to feed the first pig! Oh no! What about the other pigs? The farmer says, "That's okay, Emily! I'll feed the others later!" So in the end, Emily only fed this pig!
EXPERIMENTER: Hi Lyn, what happened in the story?
LYN: Emily fed pigs!



Plural test sentence: Emily fed pigs (target: NO)

Figure 4 Final image accompanying the plural test sentence *Emily fed pigs*.

As seen in (20) and in Figure 4, emphasis was placed on the single pig that was fed. As explained in Tieu et al. (2014, 2017), to make it very clear that only that particular pig was fed, the prompt contained the focus particle *only* and a demonstrative determiner (i.e. *Emily only fed this pig!*); moreover, a red arrow was added to the picture and the experimenter gestured to the pig when referring to it.[21] Participants who computed the plurality inference in the upward-entailing condition

21 Tieu et al. explain that this was also meant to highlight the episodic nature of the description, i.e. that there was a single event involving the feeding of one pig in particular, rather than an ongoing activity of pig-feeding.

were expected to reject the sentence *Emily fed pigs*, since it was false that Emily fed more than one pig.

For the downward-entailing condition, the stories followed the same structure as above except that the test sentences included negation. Example (21) provides a sample target and Figure 5 provides the image corresponding to the outcome of the story in (21). Participants were expected to reject the negative test sentences, which would indicate cancellation of the multiplicity inference. It was possible, however, that some participants might accept the negative targets, accessing a marked reading along the lines of *Emily didn't feed giraffes, because she fed only one!*

(21) Story: Emily is visiting the zoo today. It's lunchtime for the animals. Emily has just enough food to feed this very tall giraffe! Oh no! What about the other giraffes? The zookeeper says, "That's okay, Emily! I'll feed the others later!" So in the end, Emily only fed this giraffe!
EXPERIMENTER: Hi Lyn, what happened in the story?
LYN: Emily didn't feed giraffes!

Plural test sentence: Emily didn't feed giraffes (target: NO)

Figure 5 Final image accompanying the plural test sentence *Emily didn't feed giraffes*.

We also included two positive and two negative control items designed to elicit the opposite responses to those of the test trials. In addition to helping to make sure participants stayed on task, the addition of these controls allowed us to ensure that the participants could accurately accept and reject sentences where appropriate. The positive controls involved two positive plural sentences in contexts that satisfied the plurality inference (e.g., (22)), and two negative plural sentences in contexts that did not satisfy the inference (e.g., (23)):

(22) Plural-positive control
Context: Sammy painted two birds.
Sentence: Sammy painted birds. (target: YES)

(23) Plural-negative control
Context: Sammy drew one cat.
Sentence: Sammy didn't draw dogs. (target: NO)

All participants also received four negative control sentences that contained a definite noun phrase rather than a bare plural or an indefinite *a*-noun phrase. The negation control trials could be associated with either a *yes*- or *no*-target, which were selected based on participants' responses on the test trials. This allowed an overall balance of *yes*- and *no*-responses. An example of a negation control is provided in (24). Participants had to meet a pass rate of 75% on target utterances.

(24) Negation control
Context: Lucy could either walk the dog or take a nap, and she decided to walk the dog.
a. *Yes*-target: Lucy didn't take a nap.
b. *No*-target: Lucy didn't walk her dog.

2.2.4 Results and discussion

All participants passed the plural and negation controls and were included in the analysis. Figure 6 displays the percentage of responses consistent with the computation of plurality inferences, across the upward-entailing and downward-entailing conditions.

A mixed effects logistic regression model was fitted to the data with Monotonicity (UE vs. DE), Group (BAs vs. TAs), and their interaction as fixed effects, and with random intercepts for participant and random slopes for condition by participant. Subsequent model comparisons revealed a significant main effect of Monotonicity ($\chi^2(1) = 25, p < .001$), no significant effect of Group ($\chi^2(1) = 1, p = .32$), and no significant interaction between Group and Monotonicity ($\chi^2(1) = .08, p = .78$). Subsequent simple effect analyses revealed a significant effect of Monotonicity for both the typical adults ($\chi^2(1) = 24, p < .001$) and the participants with Broca's aphasia ($\chi^2(1) = 4.3, p < .05$).

These results indicate that individuals with Broca's aphasia can successfully compute multiplicity inferences and do not differ from typical adults in this regard. Like the typical adult group, the aphasic group computed multiplicity inferences more often in upward-entailing than in downward-entailing contexts, exhibiting sensitivity to monotonicity in line with the performance of the typical adult controls.

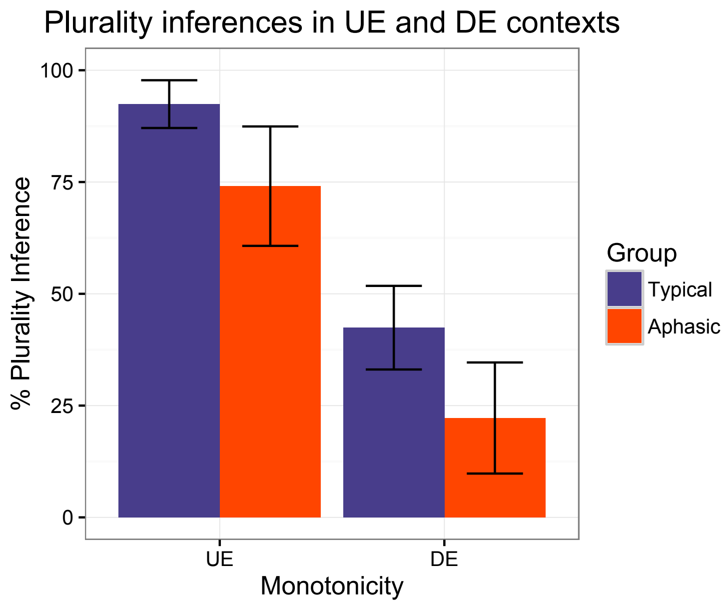


Figure 6 Percentage of responses consistent with the computation of plurality inferences. Computing the plurality inference corresponded to rejections in the upward-entailing condition and to acceptances in the downward-entailing condition.

In sum, the main finding of this experiment is that, consistent with their performance on classical scalar implicatures, individuals with Broca's aphasia can compute multiplicity inferences. Taken together, the results of Experiments 1 and 2 provide evidence for successful comprehension performance in this population in a novel domain.

Additionally, the finding that the aphasic group engaged with both classical scalar implicatures and multiplicity inferences in a similar way suggests that the implicature account of multiplicity inferences outlined in Section 1.3 may be on the right track. These findings complement recent work in acquisition that shows that children display parallel performance on scalar implicatures and multiplicity inferences.

3 General discussion

In this paper, we report on two experiments in which we investigated semantic-pragmatic inferences in a group of individuals with Broca's aphasia, comparing their performance to a group of typical adults. We focused in particular on classical scalar implicatures and multiplicity inferences. The comparison between these inferences is particularly important given an emerging body of work that analyses multiplicity inferences as a type of scalar implicature (see, e.g., Spector 2007, Zweig 2009, Magri 2014, Sauerland et al. 2005, Tieu et al. 2014, 2017).

Our first experiment tested classical scalar implicatures and revealed that the aphasic group performed like the typical adults Specifically, they generally responded in a manner consistent with them having computed the implicatures associated with *some* and *not all*. In Experiment 2 we extended the investigation to multiplicity inferences. The results mirrored those of Experiment 1, indicating individuals with Broca's aphasia computed multiplicity inferences just as the typical adult group did. These findings are consistent with the multiplicity as implicature account (e.g., Spector 2007, Zweig 2009, Magri 2014, Sauerland et al. 2005, Tieu et al. 2014, 2017). We come back to this discussion in section 3.2.

3.1 Implications for accounts of Broca's aphasia

The finding that the participants with Broca's aphasia performed like the typical adult group on scalar implicatures is surprising in light of arguments in the literature that implicatures are associated with a processing cost (e.g., Huang & Snedeker 2009, Chemla & Bott 2014). Given the evidence for a processing impairment in this population and their observed impaired performance on complex syntactic phenomena, the results of the present study beg the question of why implicatures are not likewise impaired in Broca's aphasia. Two possible explanations immediately come to mind. First, the results could indicate that the specific mechanisms that are responsible for scalar implicatures are spared in Broca's aphasia. Alternatively, the results could indicate that implicatures are not as costly as some previous studies have suggested or that at least some implicatures are relatively cost free for the processing system.

Under the first hypothesis, the results are surprising to the extent that evidence for a processing cost associated with implicatures is convincing. From that perspective, the results appear to suggest that the cost of 'complexity' poses less of a problem outside of the syntactic domain. In turn, this result could provide evidence against a domain-general resource reduction account (e.g., Crain et al. 2001, Dick et al. 2001, Zurif et al. 1993, Kolk 1995, Caplan et al. 2013) and suggest a more natural explanation within an account that assumes a syntax-specific processing impairment in this population (Grodzinsky 2000, Friedmann & Gvion 2003, Burkhardt et al. 2008).

One way to maintain a general processing-impairment account of Broca's aphasia would be to assume that scalar implicatures are not impaired because they are not as costly as previously assumed. This would be consistent with some recent reaction time data (Schwarz 2015) and eye-tracking data (e.g., Grodner et al. 2010, Breheny et al. 2013) that appear to indicate that implicatures are computed rapidly and not delayed relative to the computation of literal interpretations. Adopting this view would offer a more unified perspective of aphasic performance across a range of phenomena, with performance deviating from that of typical adults specifically in cases where there is a substantially increased processing load. This view would also be consistent with certain processing-based accounts of comprehension in Broca's aphasia, which propose that complex linguistic phenomena are differentially affected depending on their relative complexity (see Caplan et al. 2013 for a review of the evidence for such an account). On this view, implicatures and the relevant syntactic phenomena would simply fall on different points of the processing-complexity scale.

Finally, it is worth considering the implications of the present findings for recent proposals that derive scalar implicatures via grammatical mechanisms, namely by inserting exhaustivity operators akin to *only* directly into the syntactic structure. One might be tempted to interpret the success of the aphasic group on scalar implicatures as evidence against such a grammatical approach, in line with parallel arguments by Davidson et al. (2009) from a developmental Sign Language perspective. However, there are two points that would speak against drawing any strong conclusions along these lines: first, it's not clear that the grammatical complexity of implicature configurations on such accounts is on par with other cases of syntactic complexity where aphasic performance deviates from that of typical adults; the extent of the processing load involved might simply not exceed the relevant threshold, along the lines discussed above. Second, given that the status of Broca's aphasia as a grammatical impairment is still a matter of debate, we would urge caution against leaping to any conclusions about the grammatical vs. pragmatic status of implicatures, based on the performance of our participants with Broca's aphasia.[22]

3.2 Implications for the implicature account of multiplicity inferences

Consistent with the findings from Experiment 1 regarding classical scalar implicatures, the results of Experiment 2 indicated that individuals with Broca's aphasia can successfully compute multiplicity inferences, and that their performance did not differ from that of typical adults. Notably, the performance of the aphasic group could not simply be related to random guessing behavior as, just like the typical adults, they computed more multiplicity inferences in upward-entailing than in downward-entailing contexts. Of course, as each of these experiments employed different methods and materials, we cannot directly compare their performance on the two kinds of inferences. However, the overall parallel pattern we observe

22 Thanks to Kathryn Davidson (p.c.) for discussion on this point.

across implicatures and multiplicity inferences appears to be consistent with the uniformity predictions of the implicature account of multiplicity inferences. This work thus further adds to the emerging developmental evidence in support of this theoretical approach (e.g., Sauerland et al. 2005, Tieu et al. 2017). Future work could aim to directly compare the performance of individuals with Broca's aphasia on a wider range of inferences that have been analysed in the theoretical literature as implicatures.

4 Conclusions

In this paper, we have reported the findings of two experiments which investigated the computation of scalar implicatures and multiplicity inferences in a group of individuals with Broca's aphasia. The main findings were that individuals with Broca's aphasia can successfully compute both classical scalar implicatures and multiplicity inferences associated with plural sentences in positive contexts. The implications of these findings are two-fold: first, they provide evidence for comprehension on par with that of typical adults in a novel domain, indicating that either Broca's aphasia does not involve a domain-general processing limitation, or alternatively that implicatures may not incur as much of a processing load as previously argued. Second, the findings contribute to the emerging literature on multiplicity inferences, and support an analysis of such inferences as a type of scalar implicature.

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Appendix

Actives	Subject clefts	Passives	Object clefts	Total C	Total NC
10	8	5	3	18	8
8	10	3	4	18	7
10	9	3	3	19	6
10	8	5	3	18	8
10	8	6	2	18	8
8	8	3	4	16	7
8	4	4	3	12	7
7	9	6	4	16	10
7	8	2	1	15	3

Table 2 Scores on the sentence comprehension subtest of the Verb and Sentence Test (Bastiaanse et al. 2003), from the participants with Broca's aphasia.

Study ID	SS	AVC	R	N	AQ
A1	10	2.9	5.5	8.8	54.4
A2	12	3	4.2	3.7	45.8
A3	12	3	3.2	5.6	47.6
A4	10	3	5.5	5.7	48.4
A5	12	2.9	5	9.3	58.3
A6	13	3	4.4	5.6	52
A7	5	2.7	2	4.4	28.2
A8	12	3	4.7	4.6	54.6
A9	13	2.7	3.2	6.1	50
Mean	11.1	3.2	4.2	6.1	4 9.2

Table 3 Scores on the individual subtests of the WAB and Aphasia Quotients (AQs) (Kertesz 1982), from the participants with Broca's aphasia.