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Usage-based Approaches to Aphasia

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1. Introduction: Aims and Scope

A frequent piece of advice about talking to people with aphasia is "Use common words". That advice reflects the intuition that frequent and highly familiar content words may be more readily available to a person with aphasia than rare and unfamiliar ones. Evidence consistent with that intuition has steadily accumulated in the aphasia research literature, as attested by other papers in this issue and the literature cited in them see e.g. Kittredge, Dell, Verkuilen, and Schwartz (2008). Reverse frequency effects, when they occur, are seen as surprising and in need of explanation (Balota, Burgess, Cortese, & Adams, 2002; Marshall, Pring, Chiat, & Robson, 2001). In neurotypical speakers, effects of lexical frequency on the speed and ease of lexical access are amply documented, starting with Preston (1935, cited in Levelt, 2013), Howes & Solomon (1951) and Oldfield & Wingfield (1965). At this point, the idea that frequency affects lexical access and retrieval in neurotypical speakers is incontrovertible. Therefore, if there were no frequency effects on lexical access in aphasic speakers, we would have to explain how aphasia could wipe them out.

Effects of frequency and probability on comprehension and production of *sentences* have also been amply documented in neurotypical speakers (cf. section 2 below). And yet, frequency and probability effects at the sentence level have received considerably less attention in the aphasia literature, which has tended to look elsewhere for explanations of sentence-level impairments in aphasia, - despite the fact that, just as in the case of lexical frequency, an absence of such effects in speakers with aphasia would call for an explanation.

This paper has three aims. The first is to summarize available evidence in support of usage-based probabilistic models of aphasic sentence comprehension and production. We show that such evidence has been available for a long time now, but has lacked visibility. Our second aim is to respond to specific challenges for such approaches as articulated in one of the few papers (Bastiaanse, Bouma, & Post, 2009) that address usage-based explanations directly and compare them to the movement-based complexity model that is prevalent in the aphasia literature. The third aim is to discuss some of the reasons why probabilistic models in aphasia have been far slower to gain traction in aphasiology than in psycholinguistic research of sentence comprehension and production outside of aphasia.

2. Background

Before we can comment on arguments for and against probabilistic models in of sentence comprehension and production in aphasia, we must turn to evidence in support of probabilistic models more generally. The general idea underlying probabilistic models of sentence processing is that the probability of encountering a linguistic structure, given some context, affects sentence processing. Sentences and parts of sentences that are highly predictable, given their context, are faster and easier to process than less predictable ones. "Context" includes syntactic, semantic,

and prosodic information, as well as situational context, i.e. real-life settings and communicative goals.

Models incorporating the contextual and lexically-conditioned predictability of linguistic usage play a prominent role in psycholinguistic studies of sentence comprehension and production in neurotypical speakers (Bates & MacWhinney, 1987; Chater & Manning, 2006; Christiansen & MacDonald, 2009; Gennari & MacDonald, 2009; Gibson, 2006; Hale, 2003; Haskell, Thornton, & MacDonald, 2010; MacDonald, 1994, 1999, 2013; MacDonald, Pearlmutter, & Seidenberg, 1994; MacWhinney & Bates, 1989; Trueswell & Tanenhaus, 1994; Trueswell, Tanenhaus, & Kello, 1993). Theoretical frameworks differ widely as to what is held to be predictive of processing - how predictability is to be estimated, and what exactly makes predictable material easier to process - as well as in the explanations given for the existence of effects of such effects. What these frameworks – sometimes collectively referred to as "probabilistic" (see e.g. Bod, Hay, & Jannedy, 2003) – have in common is the underlying assumption that language processing reflects adaptations to probabilistic information about linguistic usage – the individual's information about any kind of linguistic probability comes from his or her experience with language. In the present discussion, we collectively refer to all such approaches as "usage-based", to emphasize the fact that the contextual information may include communicative settings in the broadest sense.

Importantly, probabilistic models of sentence processing do not claim that the frequency of any linguistic structure is necessarily a predictor of processing difficulty of that structure. To begin with, it is not frequency *per se* that is relevant, but probability given some context. Not all conceivable frequency counts enter into the probability estimate. Which counts do affect probabilistic parsing, and what other types of information besides frequencies enter into probability estimates has been a matter of empirical research for several decades (see e.g. Jurafsky, 2003, for an overview). The earliest psycholinguistic studies of frequency effects focused on (unconditioned) lexical frequency. High-frequency words tend to elicit shorter reaction times, compared to low-frequency words. Effects of lexical frequency were taken as a fairly direct reflection of how quickly words are retrieved from the lexicon and processed subsequently (Balota & Chumbley, 1985). The idea that frequent words might have a processing advantage was extended to pairs of words (Krug, 1998; MacDonald, 1993). Some frequent word pairs contain words that rarely appear outside of the pair: For example, the word *hermetically* is rare outside of the expression *hermetically sealed*. Therefore, the study of word frequency and word pair frequency led naturally to the idea that estimates of frequency must consider probability estimates based on contextual frequencies. The conditional probability of a word given the preceding or following word, often referred to as a word's transitional probability, is an example.

Effects of contextually-conditioned probabilities of words led to the idea that other types of conditional probabilities might be important, as well. A "conditional probability" is an estimate of some outcome given some condition: For example, one might estimate the probability of

encountering a direct object, given the verb *sneeze* (which rarely takes a direct object, except in the now-classic example *Pat sneezed the napkin off the table*, Goldberg, 1995) vs. *devour* (which nearly always takes a direct object). These estimated probabilities that are conditioned on particular verbs are often known as "subcategorization probabilities" or "verb bias". Subcategorization probabilities are distinct from the unconditioned probability of encountering particular types of syntactic arguments (direct objects, in our example) generally. Effects of subcategorization probabilities or verb biases quickly came to be central in papers establishing the role of probabilities in sentence processing: For example, the notorious difficulty of "garden-path" sentences like *The horse raced past the barn fell* (Bever, 1970) was found to be due in part to the high suitability of *horse* representing an agent of *race* (Altmann & Steedman, 1988; Tanenhaus, Carlson, & Trueswell, 1989), and in part due to the fact that *race* is far more often intransitive than transitive (MacDonald et al., 1994)*,* i.e. the verb's transitivity bias. A series of papers (Boland & Tanenhaus, 1991; Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Trueswell & Tanenhaus, 1994; Trueswell et al., 1993) established beyond doubt that "verb biases" and other lexically-conditioned probabilities affect sentence processing.

We emphasize the point that verb bias and other subcategorization probabilities are conditioned on particular lexical items: The difficulty of *The horse raced past the barn fell* is <u>not</u> due to the relative frequency of intransitive vs. transitive sentences generally, for example, or to the relative frequency of intransitives vs. reduced relative clauses, as attested by the ease of processing sentences like *The sign posted on the fence says to keep out*. In fact, effects of frequencies of syntactic patterns that are not conditioned on lexical items have been far more elusive than lexically-conditioned effects. The most robust effects that might be attributable to (unconditioned) "constructional frequency" may be those of active vs. passive and subject clefts vs. object clefts: Active transitives are more frequent than passives, and they are also easier to process, other things being equal. Similarly, subject clefts (*It was mostly the noise that bothered us*) are more frequent and easier to process than object clefts (*It was mostly the noise that we heard*) (Miyake, Carpenter, & Just, 1994; Roland, Dick, & Elman, 2007). But even the relative difficulty of passives as compared to actives has been shown to be lexically conditioned: For example, the verb form *elected* is more likely to be used in a passive construction than in an active, whereas *kissed* is more likely to be active. Lalami (1997) showed that, in neurotypical speakers, comprehension accuracy of passives varied with the relative frequency of passive vs. active verb uses so as to make passives easier to process than actives for passive-bias verbs. For example, a sentence like *The candidate elected for governor was very pleased* may well be easier to process than a sentence like *The candidate elected to change the topic*}. The pattern of greater difficulty with passives than actives (in neurotypical speakers) is only robust with highly transitive (and active-bias) verbs. Earlier, we made the point that the absence of frequency effects in aphasia would require an explanation. That point should also apply to effects of probabilistic parsing more generally, including effects of verb bias and other subcategorization probabilities: An absence of such effects should lead to atypical comprehension and production patterns.

In summary, effects of probabilities based strictly on the frequency of syntactic patterns, i.e. unconditioned on lexical items, have been elusive (cf. Jurafsky, 2003 for a more extensive review). However, this elusiveness of effects of constructional frequency has not lead to a rejection of probabilistic parsing theories in psycholinguistics. Instead, it has led researchers to estimate probabilities not just based on syntactic construction frequencies, but conditioned on contextual and lexical information.

3. Probabilistic sentence processing in aphasia

As we have indicated, the evidence from sentence processing in neurotypical speakers strongly suggests that the comprehension difficulty of actives and passives, and of unaccusatives vs. other kinds of intransitive verbs, must reflect lexical as well as syntactic information – specifically the probability of a given verb occurring in active vs. passive clauses. Patterns like these are fully expected under functionalist models of sentence processing in aphasia (cf. Bates & Goodman, 1997), but have received surprisingly little attention.

Russo, Peach & Shapiro (1998) documented what might be considered an absence of effects of verb bias in speakers with fluent aphasia. Russo et al. hypothesized that such speakers might be insensitive to verb bias. That hypothesis was based on earlier observations suggesting that speakers with fluent types of aphasia were insensitive to other aspects of verb argument structure information (Shapiro & Levine, 1990). Russo et al. (1998) used a cross-modal lexical decision task to compare the processing of sentences with verbs in their preferred (i.e. higher probability, other things being equal) vs. non-preferred (lower probability) subcategorization frame. Participants listened to transitive and intransitive sentences over headphones and were asked to make a lexical decision on a visually-presented probe. The probe items appeared near the point in the sentence signaling whether the sentence was transitive or intransitive (for example *The ageing pianist taught his * solo with great dignity* or *The ageing pianist taught with his * entire family*). For the group of five control participants without history of neurological disease, lexical decision times were longer for sentences in which verbs appeared in their non-preferred subcategorization frames (e.g. transitive uses of intransitive-bias verbs). No such effect was observed in the group of participants with fluent aphasia (2 anomic, 1 Wernicke's, and 1 conduction aphasia; data from a second participant with Wernicke's aphasia were excluded from analysis because all of the participant's response times exceeded 2000 milliseconds). Russo et al. interpreted this finding to mean that "subjects with aphasia do not use argument structure to assist with comprehension of sentences after lexical information associated with a verb is activated" (Russo et al., 1998, p. 544).

An alternative interpretation of the findings in Russo et al. would be that argument structure was indeed used, but that the timing of the processes involved in sentence comprehension (processing argument structure and syntactic structure) was slower in the participants with aphasia compared to the neurotypical controls. The participants with fluent aphasia had a great

deal of difficulty comprehending the sentences, as one might expect (the error rate on the yes/no questions probing comprehension of the sentences was 36% for the participants with aphasia, compared to 13% for the controls), but the analysis of lexical decision times was based on the trials with correct responses on both lexical decision and sentence comprehension question. If one assumes that some of the 64% correct responses to the comprehension questions reflected actual comprehension of the sentences, then it is likely that the participants did use argument structure information eventually, perhaps after the point in time that was tapped by the lexical decision task. Viewed in this way, the results in Russo et al. do not suggest that aphasia "wiped out" any frequency effects, but that information associated with verbs may have been processed more slowly in participants with aphasia compared to the neurotypical controls. That conclusion is consistent with much work linking sentence comprehension difficulties in aphasia to difficulties with lexical retrieval, particularly the retrieval of verbs and information relating to verb argument structure (e.g. Berndt et al., 1997; for recent evidence cf. Dickey & Warren, 2015).

Russo et al.'s observations illustrate the potential for frequency-based effects to play out differently in speakers with and without aphasia. Russo et al. analyzed response times, leaving open the question whether verb biases might also affect comprehension accuracy. Gahl (2002) hypothesized that effects of verb bias and other probabilistic parsing effects might help explain patterns of comprehension impairments in aphasia. Gahl (2002) tested this hypothesis for verb transitivity by means of a plausibility judgment task using intransitive and (active and passive) transitive sentences, e.g. *The assistant shut the store*, *The store got shut by the assistant*, and *The store shut at six o'clock*. Crucially, the verbs in Gahl (2002) differed in the frequency with which they were used in transitive and intransitive sentences, as estimated from corpus counts: One group of verbs was most often transitive, and the other intransitive. In the intransitive and the passive sentences tested, 'undergoer' noun phrases preceded the verb forms (e.g. *The door was opened by my neighbor*, *The door opened after a short while*); in the active transitive sentences (*My neighbor opened the door*), the undergoer followed the verb. Consistent with the hypothesis, a mixed group of eighteen participants with aphasia (six people with Broca's aphasia, four with Wernicke's, two with conduction, and six with anomic aphasia, as classified by the Western Aphasia Battery, Kertesz, 1982) performed better on sentences that matched the verb's "preference" for transitive vs intransitive use.

Gahl (2002) did not target the active vs. passive distinction, which has played a key role in studies arguing for the independence of syntactic and semantic information in aphasic sentence comprehension. Verbs were simply classified as transitive-bias vs. intransitive-bias verbs, without taking into account the frequency of active vs. passive verb uses. But if the relative frequency of active vs. passive uses of a given verb and the relative order of undergoer and verb for that verb both affect processing difficulty, as one would expect under a usage-based account, then the relevant corpus counts must differentiate active vs. passive verb uses. Therefore, a subsequent study (Gahl et al., 2003) targeted the active-passive and undergoer-agentive

distinctions more directly, in a study probing four types of syntactic frames: active transitive, passive, intransitive-undergoer (roughly, unaccusative) (e.g. burst) and intransitive-agentive (e.g. walk), testing eight participants with various types of aphasia. It was found that comprehension of each sentence type was better overall when sentence type and verb bias matched than when they did not. The analysis of each individual participant's ability using A' (Pollack & Norman, 1964) as a sensitivity test to distinguish plausible from implausible sentences yielded some evidence for effects of verb bias in all eight individuals. However, the study suffered from some serious limitations. For example, the statistical analyses failed to take into account individual variation across participants. More importantly, the number of participants was small, and there was considerable unaccounted-for individual variation.

More recent evidence adds support to the notion that aphasic sentence comprehension reflects the interaction of verb biases with the context in which a verb is used. DeDe (2012) demonstrated that verb transitivity bias affected listening times in a self-paced listening experiment in a group of individuals with aphasia (n = 12, including both fluent and non-fluent aphasia types): Participants listened to sentences with temporary ambiguities, such as *While the parents watched the child sang a song with her grandmother*. DeDe concludes that "the people with aphasia had slowed access to and/or integration of the lexical and prosodic cues." That conclusion is consistent with the alternative interpretation of the findings in Russo et al. (1998) mentioned above. DeDe (2013a) examined reading times in sentences such as *The talented photographer accepted the fire could not be prevented*. These sentences are temporarily ambiguous between a direct object of accepted (*…accepted the fire as inevitable*) and the subject of a sentential complement (*accepted that the fire was inevitable*). Such sentences have been studied extensively in neurotypical speakers (see e.g. Garnsey et al., 1997). DeDe (2013a) found that reading times in people with aphasia were shorter when verbs were in the syntactic environment that matched their bias than when they were not. In a separate study, DeDe (2013b) showed similar pattern of results for verbs that are frequently transitive (e.g. call) vs. intransitive (e.g. dance). This evidence is consistent with the notion that verb bias and other types of contextually-conditioned probability affect sentence comprehension – and production – in people with and without aphasia. Along related lines, (Caplan, Michaud, & Hufford, 2013) have pointed out the compatibility of information-theoretic probabilistic models of sentence comprehension (Hale, 2003; Levy, 2008) with resource-based accounts of aphasia. However, the amount of available evidence from people with aphasia is still dwarfed by the copious literature on usage-based language processing that is based on neurotypical speakers.

4. Response to Bastiaanse et al. (2009)

In our experience, usage-based approaches to aphasia have generally been met with skepticism or silence from researchers who prefer other approaches. One paper that does engage with usage-based approaches is Bastiaanse et al. (2009). We think that the arguments in that

paper are well worth considering, particularly since it states explicitly what many other authors seem to assume implicitly.

Bastiaanse et al. examine several sentence types that had figured in previous studies of "agrammatic" speech (Bastiaanse & Koekkoek, 2003; Bastiaanse & Thompson, 2003; Bastiaanse & van Zonneveld, 1998, 2005). As the authors note, "agrammatism" has been characterized either as due to compromised linguistic representations (Friedmann, 2000; Grodzinsky, 1990) or as impaired processing abilities operating on intact representations (Bastiaanse & Van Zonneveld, 2005; Thompson, 2003). The studies just cited, and many others, share the descriptive characterization of agrammatism as an impaired ability to produce and comprehend certain types of syntactic structures. Bastiaanse et al. acknowledge the possibility that frequency of use might conceivably account for the reported patterns of difficulty and examine whether such an account appears to be feasible for the sentence types in question. Bastiaanse et al. (2009) analyze three syntactic alternations in Dutch: (1) "verb movement", specifically the alternation distinguishing clauses with Subject-Object-Verb ("verb-final") order, such as embedded clauses containing finite verbs, vs. Subject-Verb-Object ("verb second") clauses, such as matrix clauses containing finite verbs; (2) "object scrambling", affecting whether direct objects precede or follow adverbial phrases; and (3) transitivity alternations, specifically the Dutch alternation analogous to English alternations such as *The boy broke the glass* and *The glass broke*, i.e. between transitive and 'unaccusative' uses of certain verbs.

To test whether the pattern of relative difficulty of the syntactic patterns in each of these alternations could be explained as a frequency effect, Bastiaanse et al. obtained corpus counts of the frequency of each sentence type. Bastiaanse et al. also counted the frequency with which each verb that was tested appeared in each syntactic pattern (e.g. SVO or SOV; transitive vs unaccusative). Bastiaanse et al. tested whether sentence types that were previously found to be particularly difficult were generally less frequent than less difficult sentence types. That was not the case. For example, verb-second position (the more "difficult" sentence type) was clearly more frequent than verb-final position, and this was true for all verbs included in the study. Bastiaanse et al. also asked whether difficulty varied with the relative frequency of verb-final vs. verb-second position for each of the verbs that were tested. For example, accuracy might have been higher (or lower) for verbs that frequently appeared in verb-final sentences. No such frequency effect was found – as was to be expected, given that second position was clearly more frequent than final position for all the verbs that were tested. Since it was the more difficult sentence type that was more frequent than the less difficult one, Bastiaanse et al. conclude that neither construction frequency nor verb-specific construction frequency could possibly explain the observed pattern of difficulty, and that the structural analyses of these such patterns are superior to a frequency-based account.

But the frequency of sentence types (e.g. transitive vs. unaccusative, verb-second vs. verb-final) is exactly the kind of frequency information that has failed to be predictive of sentence processing in neurotypical speakers. So there is no reason to expect that such effects should

emerge in speakers with aphasia. As mentioned in section 2 above, probabilistic models of sentence processing do not entail that the relative frequency of two sentence types should be predictive of their relative difficulty; many other lexical and contextual factors enter into the probability estimates.

The verb-specific frequency counts are a more promising place to look for probabilistic effects based on corpus frequencies. However, Bastiaanse et al. (2009) found that the proportion of verb-second vs. verb-final clauses did not vary much across the verbs that were included in the study, consistent with their conclusion that neither constructional frequency (V2 vs. V-final) nor verb-specific frequency held much promise as explanations for the observed difficulty. Indeed, the homogeneity in the verbs' "preferences" precluded testing for verb-specific effects; trying to do so would be like attempting to detect effects of blood pressure in a population composed entirely of people with high (or low) blood pressure.

Of the patterns examined in Bastiaanse et al. (2009), the unaccusative vs. transitive alternation was the only one for which verb-specific frequencies varied considerably for the verbs that were included in the study. As in the case of the alternations involving verb movement and object scrambling, Bastiaanse et al. found that the frequency of transitive vs. unaccusative uses of a verb was non-significant as a predictor of accuracy in a logistic regression model with Frequency, Group (agrammatic vs. fluent aphasia), and Condition (unaccusative vs. transitive), and the Group * Condition interaction as predictors.

As we have said, under a usage-based model, the effect of overall frequency of transitive uses need not be a significant predictor of accuracy: There is no reason that speakers would make fewer errors in both transitive and unaccusative sentences when using verbs that are frequently transitive. What we do expect is that verbs that are frequently transitive would tend to elicit fewer errors when used in their transitive (vs. unaccusative) form; the more transitive-biased a verb is, the easier its transitive forms should be (Gahl, 2002; Gahl et al., 2003; Menn et al., 2003). Conversely, the more unaccusative-biased a verb is, the easier it should be to use that verb in its unaccusative form. In a regression model, such an effect would express itself as an interaction of Condition with Frequency, not as a main effect of frequency. Of course, transitive vs. unaccusative sentences might well elicit different error rates, independently of verb-specific subcategorization bias (Menn, 2000).

The question, then, is whether the difficulty of unaccusatives varied with the verbs' bias towards unaccusative (vs. transitive) use. One way to answer that question is to compare the accuracy on transitive vs. unaccusative sentences for each verb, and ask whether the difference in accuracy (i.e. the differential difficulty) of the two sentence types varied with verb bias. Table C1 in Bastiaanse et al. shows the corpus counts of transitive and intransitive verb uses and gives the percentage of unaccusative (as opposed to intransitives that were not unaccusative) vs. transitive uses. Table C2 in Bastiaanse et al. (2009) shows the number of correct sentences produced, broken down by verb, sentence type (unaccusative vs. transitive), and aphasia type.

Based on that information, we calculated the "transitive advantage" of each verb as the difference between the number of speakers who produced a correct transitive sentence and the number of speakers who produced a correct unaccusative sentence. If verb bias matters, transitivity advantage should vary with verb bias: Verbs that are usually transitive (i.e. rarely unaccusatives) should have a greater transitivity advantage.

Figure 1 shows the data from Bastiaanse et al.'s Tables C1 and C2, plotted so as to show the relationship between verb bias and transitivity advantage, for the speakers with agrammatic aphasia. The trend line in Figure 1 represents the regression line of a simple linear regression model of transitivity advantage as a function of verb bias. It must be noted that the data as reported in Bastiaanse et al. are aggregated over participants, and a regression model based on the aggregated data violates a number of important assumptions underlying this type of regression model. For the record, the (Pearson) correlation between verb bias and transitivity advantage is non-significant ($r = .44$, $p = .12$), but again, since the model assumptions are not met, there is no point in asking whether that value is low enough to call for an explanation. For example, the speakers who produced correct sentences with unaccusative uses of, for example, *breken* ('break') were not the same ones who produced correct sentences with *draaien* ('spin'). Also, as is typically the case for studies of aphasic sentence production, the number of participants was small ($n = 8$). We are not advocating that any firm conclusions be drawn from the plot any more than from the statistical model. The point we want to draw attention to is that, based on the available evidence, there was a tendency for verbs to elicit a higher numbers of correct transitive uses if the verbs were frequently used transitively in the corpus, consistent with the predictions of a usage-based account of the data.
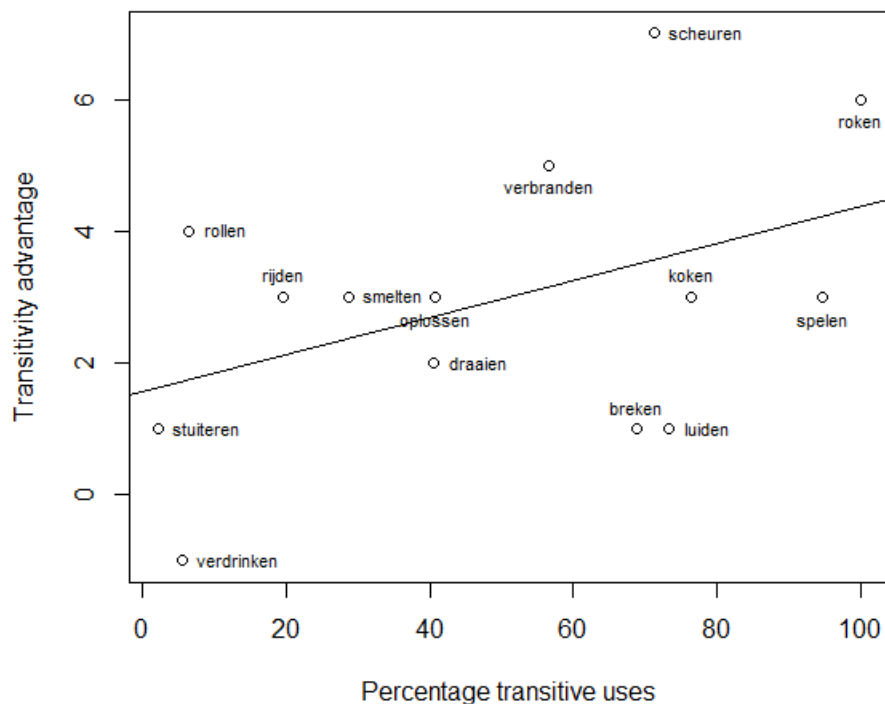
Figure 1: Verb bias (percentage of verb uses that were transitive) and transitivity advantage in correct sentences produced by speakers with "agrammatic" aphasia in Bastiaanse et al. (2009) (see text).

Figure 1 only shows the data for the speakers with agrammatic aphasia. Figure 2 shows the analogous information for the speakers with fluent aphasia. For these speakers, the trend line does not suggest any relationship between verb bias and transitivity advantage. Unsurprisingly, there is no significant (Pearson) correlation between transitivity advantage and verb bias for this group ($r = 0.24$, $p = .41$). As Figure 2 shows, the verb *rijden* may be an outlier. When that verb is excluded from the analysis, the correlation between transitivity bias and transitivity advantage reaches significance at the .05 level of significance ($r = .55$, $p = .048$). Again, the data are only available in aggregated form (as the number of correct responses), and it is impossible to be sure if there was any pattern once by-participant variation is taken into account. However, the comparison between speakers with fluent aphasia, compared to speakers with agrammatic aphasia, is intriguing in light of the fact that Russo et al. (1998) reported an absence of an effect of verb bias on comprehension in speakers with fluent aphasia types. Much more work in this area is needed, both on comprehension and on production, to clarify the relationship between the use of verb-related information in sentence comprehension and in sentence production.
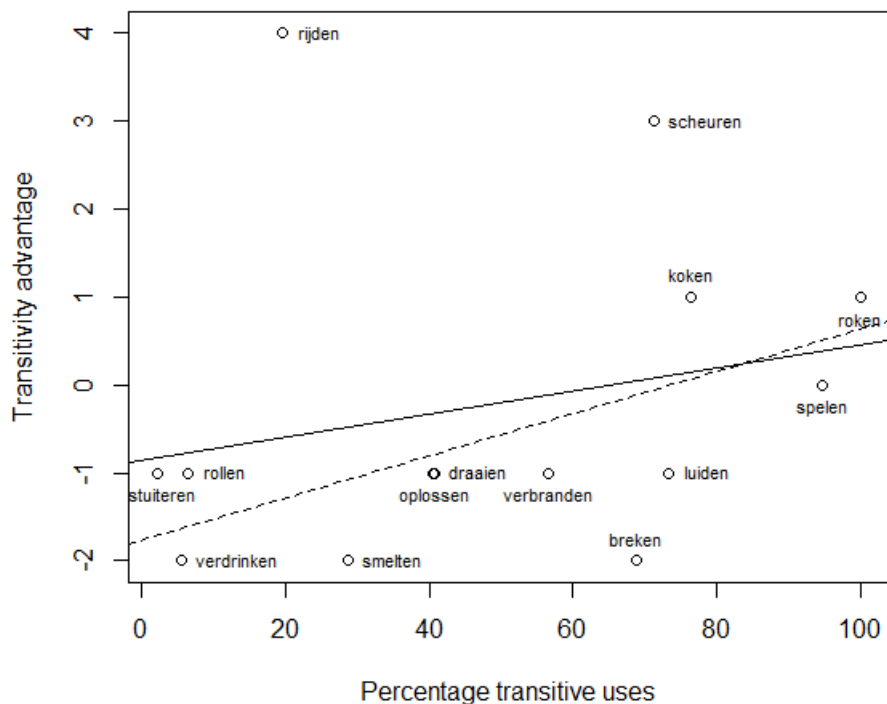
Figure 2: Verb bias (percentage of verb uses that were transitive) and transitivity advantage in correct sentences produced by speakers with fluent aphasia types in Bastiaanse et al. (2009) (see text). The solid line represents the regression line of a simple linear regression model of transitivity advantage as a function of verb bias. The broken line represents the regression line of the same type of model when the verb *rijden* is excluded from the analysis.

The relationship between transitive use and performance in the experiment leaves open the question of what causes the varying degrees of difficulty of transitives vs. unaccusatives and the other sentence types tested in Bastiaanse et al. The point of Bastiaanse et al.'s analysis is to make the case for a unified explanation of the patterns of difficulty: In Bastiaanse et al.'s analysis, each pair of sentence types considered contained one type involving movement out of a base-generated position and one that did not; in each case, the sentence type involving movement was the more difficult member of the pair. The appeal of that analysis lies in unifying seemingly disparate phenomena.

But unified explanations are only attractive to the degree one believes the phenomena to be explained to have common causes. Alternative explanations of the patterns of difficulty

presented in Bastiaanse et al. (2009) are conceivable. Subjects of unaccusatives are undergoer subjects, rather than agentives. Related to that, a sentence like *De boter smelten* ('The butter melted') <u>begins</u> with an NP denoting an undergoer, rather than an agent (Menn, 2000). Possible explanations for the other sentence types include the position of words within sentences: Sentence-final elements are easier to retrieve from memory (see e.g. Sabourin & Stowe, 2004). Evaluating alternative explanations is impossible without additional information, e.g. information about what the speakers said when they responded incorrectly. Here, we only note that the data as reported are consistent with the predictions of a model taking verb bias into account.

5. Why probabilistic approaches have been slow to gain traction in aphasiology: Heuristics vs. algorithms

We have argued that evidence for the role of frequency and predictability beyond the word level in aphasia has been available for a long time. The evidence is highly consistent with parallel findings on people without aphasia. So why is it that probabilistic parsing and other usage-based models have played such a minor role in research on aphasia research? We think it is worth reflecting on some of the reasons for the lack of visibility of the existing studies.

One fairly obvious reason for the lack of attention paid to sentence-level effects of usage probability is the fact that linguistic studies of sentence production and comprehension in aphasia have been dominated by syntactic frameworks in which frequency and predictability have little or no place. Another reason, not tied to any specific theoretical framework, is that from the very beginning of the study of agrammatic (and child) syntactic comprehension, researchers sharply distinguished between "algorithmic" (or "syntactic" or "grammar-based") language processing on the one hand, and "heuristic" ("non-syntactic" or "extra-linguistic") strategies on the other (Bever, 1970; Caramazza & Zurif, 1976).

This sharp separation of algorithmic and heuristic processes was evident in Caramazza & Zurif (1976)'s seminal paper about sentence comprehension difficulties in Broca's aphasia (for critical discussion of that paper, see e.g. Caplan, 2003; Martin, Vuong, & Crowther, 2007). Caramazza & Zurif (1976) noted that some speakers with aphasia depended heavily on the information contained in argument order and argument lexical semantics in order to interpret utterances. Relying on argument order makes it possible to interpret 'The boy who pushed the car…' without really processing the syntax of the subject relative clause; similarly, relying on lexical semantics and ignoring the syntax makes interpreting 'The apple was eaten by the boy'. But both of these cues to sentence meaning were well-known to be unreliable: Argument order information is unreliable in passives, unaccusatives, object clefts, etc., and lexical semantics is of no help in 'reversible' sentences like 'The cat was chased by the dog'. Caramazza & Zurif

(1976) argued that "the heuristic and algorithmic processes can independently assign semantic interpretations to utterances (…)" (Caramazza & Zurif, 1976, p. 582). "From the evidence at hand, these heuristics are based upon the semantic plausibility of the arrangement of lexical items and upon a sequential regularity whereby noun-verb surface arrangements can be mapped as actor-action relations (Caramazza & Zurif, 1976, p. 581). In other words, 'heuristic'(word-order, lexical semantic) and 'algorithmic' (syntactic) processes were conceptualized as separate.

Other researchers questioned whether heuristics entered into sentence processing at all – in speakers with and without aphasia. "The attempt to flesh out a theory of heuristics is admirable if it is indeed necessary to incorporate them [i.e. heuristics, SG & LM] into an account of aphasia. What would show this to be necessary is if the principle aphasics used to process sentences were not the same as those used by normals, and instead had the characteristic of being (presumably) statistically based generalizations over superficially observable properties of the input, e.g. precedence relations holding between individual words, or perhaps word classes" (Frazier & Friederici, 1991, p. 59). The authors just cited (Frazier & Friederici, 1991 and Caramazza & Zurif, 1976) differ on many fundamental points about the nature of aphasia. Yet, despite these differences, they have in common the assumption that heuristics and probabilistic strategies are separate from (and potentially absent from) "real" sentence processing.

Our position is that sentence processing does rely on the same principles in people with and without aphasia, and that "heuristics" and other processes not strictly based on syntactic structure are part and parcel of sentence processing in all speakers, as we concluded at the end of section 2, above. Speakers without aphasia rely on "heuristic" processes even when processing what would appear to be very simple sentence types (Ferreira, Bailey, & Ferraro, 2002; Wilson & Garnsey, 2004). In other words, statistically based generalizations and other "superficially observable properties" of language use are as much a part of language processing as syntactic phrase structure and syntactic dependencies, in speakers with and without aphasia.

6. Concluding remarks:

Aphasiology, syntactic theory, and psycholinguistic studies of 'normal' language processing have generally not moved in tandem. Empirical findings and theoretical developments in any one of the three often go unnoticed in the others. Of particular concern to us is the fact that studies of sentence processing in aphasia rarely include any reference to research on neurotypical sentence processing. This state of affairs would be both natural and defensible if speed and accuracy of language processing in people without aphasia were uniformly stable and robust, but that is far from being the case. If there is one thing that research on 'normal' sentence processing has made clear, it is that language processing, while amazingly robust to poor input and output conditions in some ways, is prone to fluctuations in processing speed and accuracy, and shaped by past

experience – that is, by usage in real-world contexts. We have argued in this paper that the effects of past linguistic experience are evident in the language of people with aphasia, just as they are in the language of all other speakers.

Studies of probabilistic effects at the sentence level in aphasia are essential because of the gradient nature of aphasic communication difficulties. Sentence comprehension and production are typically spared to varying degrees in aphasia, rather than being either intact or absent. Detailed and plentiful evidence that this is the case has come from studies of working memory limitations on sentence comprehension and production (see e.g. Martin et al., 2007 for an overview). Moreover, variability in aphasic difficulty is systematic: It is not completely unpredictable random variation, and one of the factors in this variability is the familiarity/probability of the utterance that is being attempted. After all, for over forty years, clinicians have known that speakers with aphasia find it easier to repeat "high probability" sequences like *I got home from work* than to repeat "low probability" sequences like *The spy fled to Greece,* and have capitalized on this fact in evaluation (the sentences are from the Boston Diagnostic Aphasia Examination; Goodglass & Kaplan, 1982). Similarly, Norman Geschwind's neuropsychology examinations at the Boston VA Medical Center, attended by author LM in the 1980s, sometimes found patients with severe aphasia who responded appropriately to "Please turn off the light," but not to "Please point to the light," while the reverse pattern was not observed. Geschwind's own explanation for this behavioral difference was in terms of differential vulnerability of various nerve fiber tracts, but we suggest that it should instead be ascribed to the much greater real-world probability of being asked to turn a light off than of being asked to point to one.

We have reviewed evidence supporting probabilistic models of aphasic sentence processing. Some of that evidence comes from the gradience and variability (but not "randomness") of aphasic sentence processing. One motivation for reviewing this evidence is that probabilistic approaches to linguistic theory and description have gained sufficient theoretical currency to serve as a reference point for researchers studying normal and aphasic language processing (Bod et al., 2003); see also Baayen et al., Gibson et al., and Ewijk & Avrutin (this volume). Similarly, the increased visibility in psycholinguistics of the cluster of usage-based linguistic theories of syntax and semantics known as Construction Grammar (Bencini, 2013; Goldberg & Bencini, 2005; Kapatsinski, 2014) has the potential, in our view, to broaden the scope of the discussion beyond the patterns of 'agrammatic' deficits that have dominated the study of sentence-level deficits in aphasia in the past.

A more general motivation for reviewing the evidence for usage-based language processing is our belief that a usage-based approach to language processing in aphasia has greater relevance to rehabilitation. Interest in life-participation approaches to aphasia rehabilitation is strong and growing (Chapey et al.; Elman, 2011; Holland & Forbes, 1993; Nelson & Butler, 2007). Two cornerstones of such approaches are (a) a focus on *preserved* abilities in individuals with aphasia

and (b) a focus on communicative needs in contexts specific to an individual and to different situations in which communication takes place. Usage-based approaches to aphasia research share both of these foci and strike us as natural companions to life-participation approaches. Effects of lexical frequencies in aphasia, viewed in the broader context of the framework we are advocating, are merely one manifestation of a more fundamental property of language: Language processing reflects memories of linguistic experience; as a result, statistically based generalizations affect language processing at all levels. We suggest that progress in research on sentence production and comprehension in aphasia depends on taking such processes into account. The study of the role of predictability in aphasic comprehension, repetition, and prompted production of decontextualized sentences is no more than a foot in the door to understanding the role of probability in aphasic communication.

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